ISSN 0144 - 1396

AYRS 118

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ULTIMATE SAILING III

Kite Sailing

Edited by Tony Kitson

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Ultimate Sailing III
Kite Sailing

Edited by Tony Kitson

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Contents

Introduction

This is the third AYRS publication in the series 'Ultimate Sailing'. The first, AYRS 114, introduced the original ideas of Professor Hagedoorn and presented Paul Ashford's account of his experiments in the development of an effective hapa. The second, AYRS 116, contained Peter Lynn's account of his development of an efficient traction kite, the Peel, and its use in kite-buggying and a design for a four-line traction kite from Chris Sands. In this publication we look at a variety of ways in which kite power has been harnessed for traction over water.

Kiteski is the system developed by Billy and Cory Roeseler using a kite, some water-skis and not a little skill to progress at speed over the water. The system has become well known through Cory's participation in the Weymouth Speed Week and the Columbia River Gorge 'Blowout' as well as a demonstration to the AYRS New England May event. Kiteski is an excellent example of how it is possible to turn what most would have regarded as a crazy dream into a commercial reality within a few years, if you have sufficient belief in and commitment to your ideas. *You also need a son who is crazy enough to try it in the first place and skillful enough now to make it look easy.*

What may be less well known is that Kiteski is just a low-speed spin-off from Billy Roeseler's long-term programme to develop a kite-powered attempt on the world sailing speed record. Billy and his partners first presented their ideas at the Ancient Interface Sailing Symposium in 1979. Here in 'Introduction to Really High Speed Sailing' and '50 Knots Now, etc', they develop these ideas further and bring us up to date with the experiments they have conducted.

The paper by CP Burgess was originally published in 1939. I am grateful to Didier Costes for bringing it to my attention. It is remarkable both that such ideas were being seriously considered at that time and that Didier should, quite independently, develop the same concept some years later. I hope to publish more on Didier's 'Zeppy' project in the next Ultimate Sailing.

There are two papers by Theo Schmidt. The first follows the ideas of Burgess and Costes regarding lighter-than-air kite/sails for propulsion but applies them to heavier-than-water craft. The second recounts some of the few attempts to apply Hagedoorn's concepts.

The correspondence between Paul Ashford and Didier Costes followed from Paul's publication in AYRS 114, and presents us with further information from two of the leading designers of Hapas. Paul has also translated, from Didier's patent documents, some more details of his Hapa designs.

Acknowledgements

The articles by Billy Roeseler et al were distilled from an abundance of material which he sent to me. I hope that he will recognise the original ideas as his own.

Walter Giger wrote a report for the newsletter on the talk and demonstration which Cory Roeseler gave to the New England group in May 1994.

Didier Costes unearthed the 1939 paper by Burgess and I am grateful to him for bringing it to my attention.

Theo Schmidt's papers, whilst not quite as early as Burgess's, have been long awaiting publication; my fault not Theo's.

I am grateful to Didier Costes and Paul Ashford for permission to publish their correspondence following Paul's paper in AYRS 114, and to Paul for his translation of Didier's French patent.

Roger Glencross and Richard Lyster have performed that function euphemistically referred to as proof reading. What they really do is to translate my texts into a language more closely resembling English.

Thanks to all and, as usual, the mistakes are all mine.

Kiteski Development

A personal history of kitesailing and kiteskiing

by Billy Roeseler

Growing up in Wisconsin, we had done some sailing as children, even put up a bedsheet on some poles and built a crude ice boat in 1955 using runners from some old skates.

In the '50s I learned to water ski behind a 15 hp outboard on some home made skis using a 14 ft aluminium kicker boat. We put a deck and steering on the boat and upgraded to 30 hp, and we even learned how to build a pyramid on water skis and put on our own ski show. Needless to say, we lived at the limit of dynamic lift, with barely enough power, using a low pitch prop, to pull a slalom skier or ski double. I was fascinated by the kite skier from Cypress Gardens, and even built a kite, but the 30 hp just didn't have the power to pull the skier fast enough to fly.

My projects in the early '60s as a student at MIT included work with Doc Edgerton and underwater photography using strobe lights. I had been certified for SCUBA back in Wisconsin in '61, and we enjoyed winter trips from Boston to Florida and the Bahamas to visit the fish. My master's thesis with Norm Ham resulted in a deployable rotor, built and tested in the MIT wind tunnel, consisting of nothing more than a ribbon of Mylar, tensioned against airloads by the centrifugal forces on a streamlined tip weight. We became aware of some of the difficulties of 'soft sails'.

The world oil crisis of the early '70s sparked my interest in wind energy, and I built my first hydrofoil sailboat. I got some real hydrofoil experience at Boeing at 43 knots on the Jetfoil, and began towing my son, Cory, on waterskis, behind my Hobie 18. By the end of the decade I had figured out how to sail really fast using kites, and published the first technical paper on Kitesailing in 1979 at the Ancient Interface Sailing Symposium in Pamona, California. My co-author, Nelson Funston, is a Ph.D glider pilot, and his experience with sailplanes in the speed range between 50 and 100 knots was essential to understanding high speed wind energy extraction. We also bought an early hang glider in '75, and the sharp contrast between flying performance of the soft sail and the rigid wing was dramatic, both in terms of lift-to-drag ratio (L/D) and controllability.

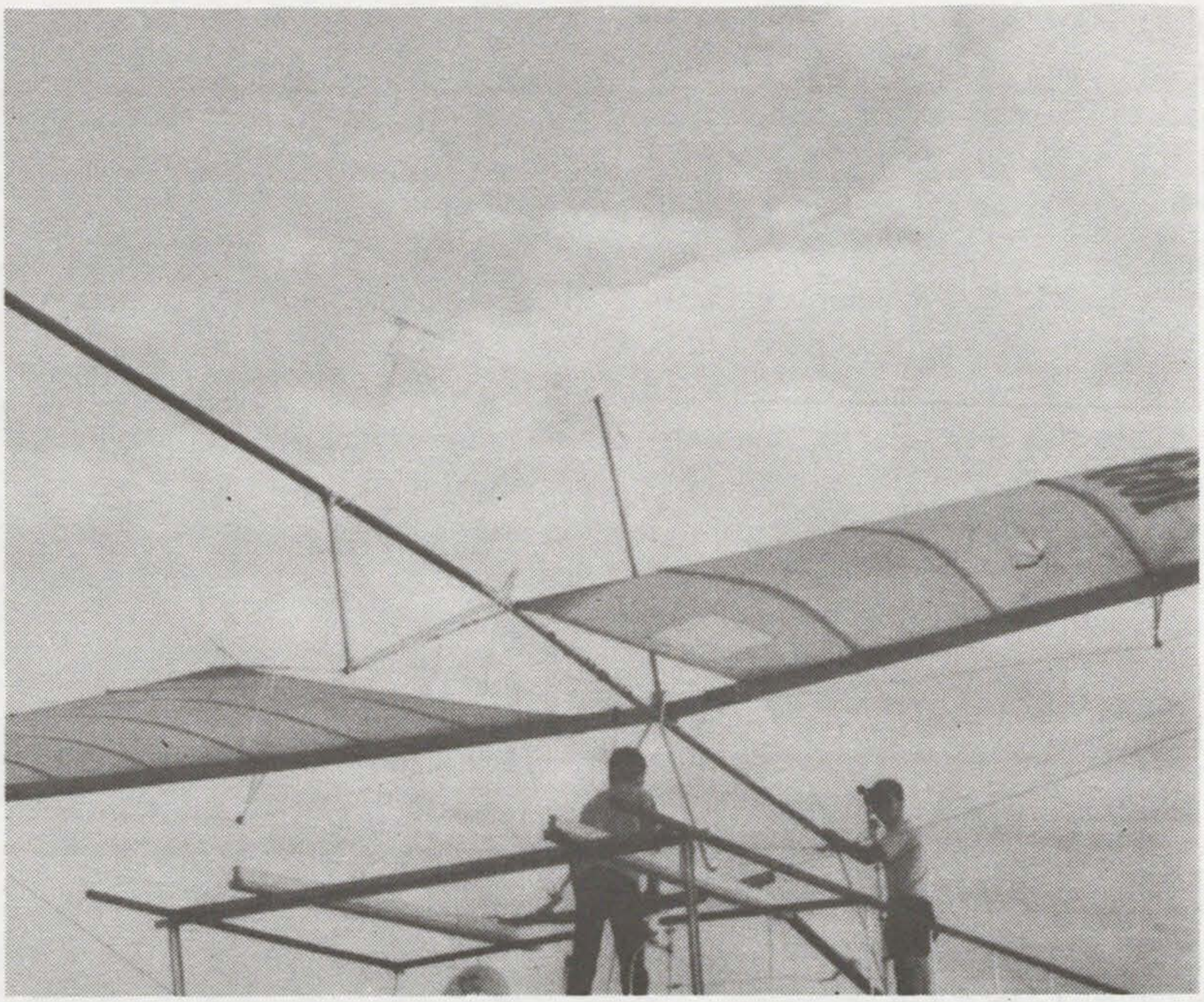
We learned clearly why the soft sails and parafoils have dominion in the speed range below 50 knots, and the rigid wings are better above 50 knots. External bracing such as risers, bridle lines, and cross tubes add little frontal area and little drag to a soft sail with a thickness-to-chord ratio (t/c) above 30%, but the same system of risers would destroy the aerodynamic efficiency of a 747 wing, which has a t/c below 10%. The drag coefficient on a line or tube held normal to the airstream is greater than 1.0, while that of an efficient streamlined shape is often less than 0.1 based on frontal area, or less than 0.01 based on planform area. There is also a profound effect of viscosity, which is a little beyond the scope of this paper, but just remember the osprey and the eagle have no external wires or struts, and they have evolved over a period of millions of years to hold dominion over the world of flying creatures. The bat and the butterfly can fly with less efficient wings, but they also benefit from the square/cube law which means that the lift increases with the square of the linear dimension while the weight increases with the cube. Hence larger flying things must be more efficient structurally in order to fly.

We bought the first Hobie 18 in Seattle in 1975 and learned how to sail up to 20 knots on the fastest production boat of the day. My son, Cory, was a pretty good waterskier when he weighed only 50 lbs, and we would tow him on one or two skis behind the sailboat, usually without an observer, and often in light air, not much above 10 knots of true wind. The Hobie would make its own wind in these conditions, beam reaching at 10 knots in 10 knots of wind, thereby enjoying 14 knots of relative wind.

Inspired by 'The 40 Knot Sailboat' by Bernard Smith, we figured out in 1979 how to sail at several times the wind speed. We co-authored a paper on high speed sailing with Nelson Funston, who had already been soaring for many years at speeds up to 100 knots in better and better sailplanes. Although we had the theory worked out, we did not get around to the experimental stages until 1984. We knew the power available from the wind would be somewhat less than we had been enjoying with power boats. We had a small 10 hp outboard motor, and we knew that was about the power we were getting from the wind during our earliest wind-powered waterski trials. One of our first projects was to find out what it would take to get a Hobie 18 up to 20 knots on 10 hp.

The first thing we had to do was to discard one of the two hulls, mounting a light-weight planing surface on the end of the one remaining cross member to provide some stability. That also cut the weight in half, but we were still only able to get about 18 knots at full throttle. We closed off the daggerboard trunk and mounted a small hydrofoil to lift the entire hull out of the water. Then, with only about three square feet of wetted area, we were finally able to get 20 knots on 10 hp. It was a funny-looking craft indeed, with motor, driver and fuel tank all perched on the aft three foot of the 18 foot hull, and with the forward 9 foot completely out of the water.

The next step was to disassemble the Jobe Sky Sail, which we had flown a few dozen times during the '70s. We made 20 flights in 1984 using the modified hang glider, a single surface Rogallo wing unswept and slotted to reduce stall speed from 20 to 10 knots. We felt the sail shape was poor, so we spent the winter building a stronger and more efficient wing from a pair of Hobie 18 rigs. This 'Big Bird' we flew 20 times in 1985 and 20 times in 1986. It had a span of 56 feet and almost 400 square feet of sail area, and with the human pilot weighed over 300 lbs. We finally got it under control, using a conventional tail with rudder and elevator similar to a light plane, but the safety of the teenage pilot became a critical issue, even though we tried to keep him just a few feet off the water. The plan was to tow a small hydrofoil boat, called a Dynafoil, using the power from the kite. The entire system weighed well over 800 lbs, and we just could not seem to get the resources together to make it sail. Even if we had, it probably would not have sailed over 20 knots.



The 'Big Bird' - A pair of Hobie Rigs

We did some of our testing off the deck of a 46-foot houseboat, which provided comfortable quarters on windy days on Lake Washington. We even put the Hobie 18 rigs on the houseboat, and managed to reduce fuel consumption by 50% in favorable winds, but that is another story.

In 1986 we discovered the modern stunt kite in San Diego, and Brook, my wife, bought me one, a Superdart by Action Kites, for Christmas. My son, Cory was so impressed with its power, we actually tried to ski with it that winter. In the early spring of 1987, we teamed the Superdart with a Hawaian and another delta kite, and we made our first successful Kiteski run. A lack of windward capability and poor logistics put Cory out in the Straights of Juan de Fuca at nightfall, and we had to get help from a nearby group of sailors.

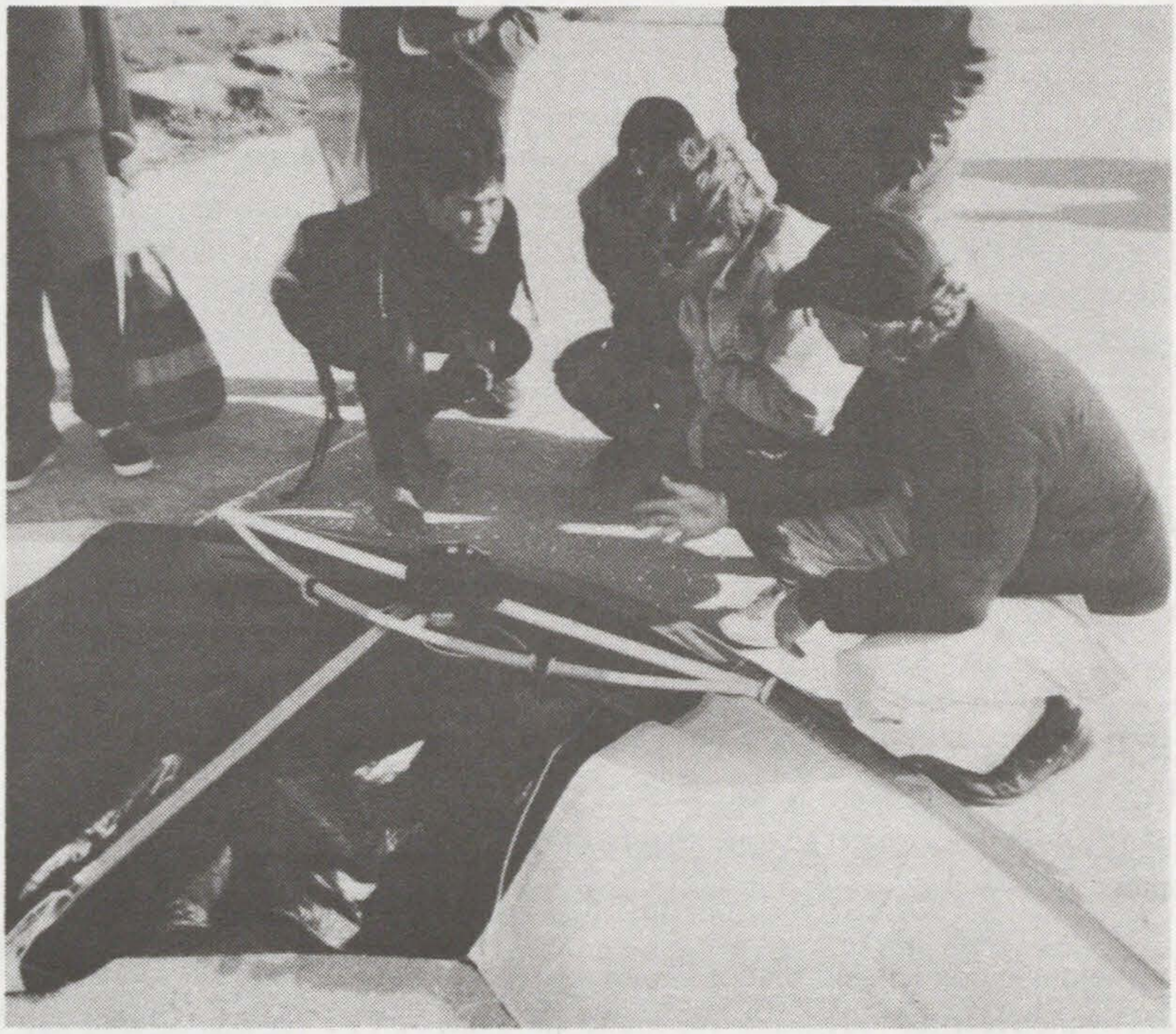
Fred Gunther introduced us to the Flexifoil, which was much faster and pulled harder than the delta kites, and we got a bunch of them from Andrew Jones so we could actually go kiteskiing. In 1988 we moved to California, where the wind and water were warmer, and then Cory got together with Dave Culp to come to Weymouth in October to win the prize in the 10 sqm class using ordinary Jobe Jumper skis and a stack of Flexifoil power kites. Our greatest victory was back in the Columbia River Gorge in July 1989 when Cory was able to get through a pack of 190 of the world's best boardsailors in a 20 mile downwind event called the 'Blowout'. His average speed over the water was almost 30 knots for 56 minutes, and the winds were gusting above 40 knots.

In 1991 we tried to develop a kite with an inflated spar to replace the expensive and fragile spars in the big Flexifoils. We were having trouble getting any of them to fly as well as the Flexifoil. Another problem was the difficulty of launching the kites after they went into the water. It took a support crew and a lot of time, and we did not think there would be a commercial market for such a system, even if it was fast. We put out a specification to the kite community to develop a kite as powerful as the 16 foot Flexifoil, that would cost less, be more durable, and would launch off the water.

Cory had worked all winter with a team from the University of California at Santa Barbara on a kite-powered all-terrain vehicle, and we met in the desert for high-speed trials. We had trouble with stacks of Flexifoils, as the force generated against the 800 lb vehicle often proved too much for the 500 lb Spectra flying lines. I had purchased a 16 foot skin from Banshee Kite, and fitted some fibreglass spars. Its power was awesome, and it looked like it might be the answer to the water launch problem.

We had Banshee make some 20 foot sails, and we got some fibreglass tube from a local builder of rakes and other yard tools. The kites were very powerful, and we thought that we might have a commercial product. We had a design review with Peter Lissaman and Jim Marshall, two good aerodynamics people in Southern California. Paul Veneklassen also reassured us that we were on the right track. We took six prototype Kiteskis to the Columbia River Gorge for high wind tests. Two of them tore at the trailing edge, and they were all too heavy to learn to fly. We went on a weight improvement programme, and Steve Maher of NoLimitz built us some good carbon spars.

Our prototypes were tested in July of '92 by a team of men and women at the Columbia River Gorge. Although they flew well and pulled hard, they were difficult to launch in winds below 10 knots, and we had to reduce the unit weight from 0.2 lb/square foot (psf) to 0.1 psf. The major changes were carbon tubes for main spar and battens. The production kites are easy to launch, and they are easy to fly at the edges of the envelope where the mass of the kite is very significant, even in heavy air.



Banshee Kite and Control Bar with Reel.

Our next six kites were half the weight of the first ones, and much more durable. The unit weight was less than a tenth of a pound per square foot, and the maximum force capability was still over 1,000 lbs. We worked for another year and 100 more kites to get an acceptable level of crashworthiness, but many of our early customers were happy with the great power, even though the high strength (100,000 psi) carbon spars would sometimes break after being crashed several times into the ground at high speed.

One of the greatest achievements of the Kiteski development was a unit cost several orders of magnitude lower than other aircraft of the day. For example the $1,000,000,000 Stealth bomber cost over 100 times more per pound than the Kiteski, even though both are made of the same materials. We also flew Peter Lynn's Peel and other sparless kites, and we have great respect for what they can do. If you want maximum power per pound of kite, then you may want to consider using a soft kite. But, if you want speed, you will find that the carbon spar with minimum bridle will win every time. Also the carbon spar has provided water launch capability superior to any of the soft kites.

For the benefit of all readers who have not yet flown a Kiteski, let me just mention it has a wing span of 20 feet, about 67 square feet of sail area, and will fly at four times wind speed in winds up to about 20 knots. Weighing just 5 lbs, its nylon, Dacron, and carbon construction permit assembly in less than 5 minutes. The six tubular carbon battens provide nearly noiseless flight, and the leading edge pocket provides a good fairing around the main spar, which has a straight length of 25 feet. There are no cross tubes, as the flex stiffness of the leading edge spar is tuned to provide just the right luff tension for relative winds up to about 80 knots. For higher speeds, we offer a stiffer spar, which will extend the efficient wind range up to 100 knots. We are still looking for a 300 lb kiteskier who wants more power.

We also offer 12 and 16 foot versions for beginners, for folks who weigh less than 120 lbs, and for big guys who happen to sail where the wind blows 30 knots every day. We are working on a 24 foot kite for folks who like to sail mostly in the 10 to 20 knot wind range. It has also proven useful when the host of the local TV show wants to learn to kiteski, and there is only 10 knots of wind. Cory maintains that he can get anyone up on a kiteski, but sometimes it takes a 24 foot span.

We held our first Kiteski school in La Paz in November '93, and six more men and women learned to Kiteski. We found that sedentary adults over 200 lbs can learn to Kiteski in less than 15 minutes if they have the basic kite-flying and waterskiing skills. The power of the 20 ft kite is truly awesome, lifting a 200 lb skier up on a plane in less than one second in winds of only 15 to 20 knots. Women and children below 150 lbs seem to prefer the 16 ft kite which, with 44 square feet of sail area, provides the same power for a 120 lbs pilot that the big kite provides for a 180 lbs pilot.

Kiteski's Banshee Kite.

Many traction kite people today seem to prefer the four line kite. Most of our customers are happy with the two lines, as we can still park the kite aloft, and we can get high angles of attack when we want them by flying the kite into the power zone, down wind and low in the sky. Even when we are buggy racing with a quad line kite, we only use the forward lines, as the back ones just create drag. The Revolution is great fun because it will fly backward, but there is little need for that while towing boats at sea. In fact, our future kites will be a single line kite with radio control, as windage on the lines can thus be further reduced.

Suggesting that all kite boats should have dead man releases is like suggesting that jam cleats should be prohibited on all catamarans. The fact is that many catamaran sailors are willing to take the risk of capsize, and it is really none of our business as kiteskier whether they have quick release mechanisms on their sheets and shrouds. Cory and his team at the University of California at Santa Barbara had a roll bar on their kite-powered all-terrain vehicle, and they wore helmets and seat belts, but that does not mean that Peter Lynn and his buggy racers need seat belts and roll bars if their safety record is acceptable.

If we work together to educate the public about the potential of kitesailing, it just may become the preferred way to get exercise or even to travel the world in the 21st century. As fossil fuels become more expensive, folks will be looking for ways of going fast and getting air that do not involve large quantities of fuel. An advanced kitesail with a 1 hp auxiliary motor could provide more air time and thrills with little or no wind than a 100 hp ski boat. As the kites begin to look more like aircraft, and tunnel boats or hydrofoils replace the skis, speeds may increase above 50 kts, and there is really no reason a kite-propelled hydroplane could not exceed 100 or even 200 kts within ten years.

A 'Water Start'.

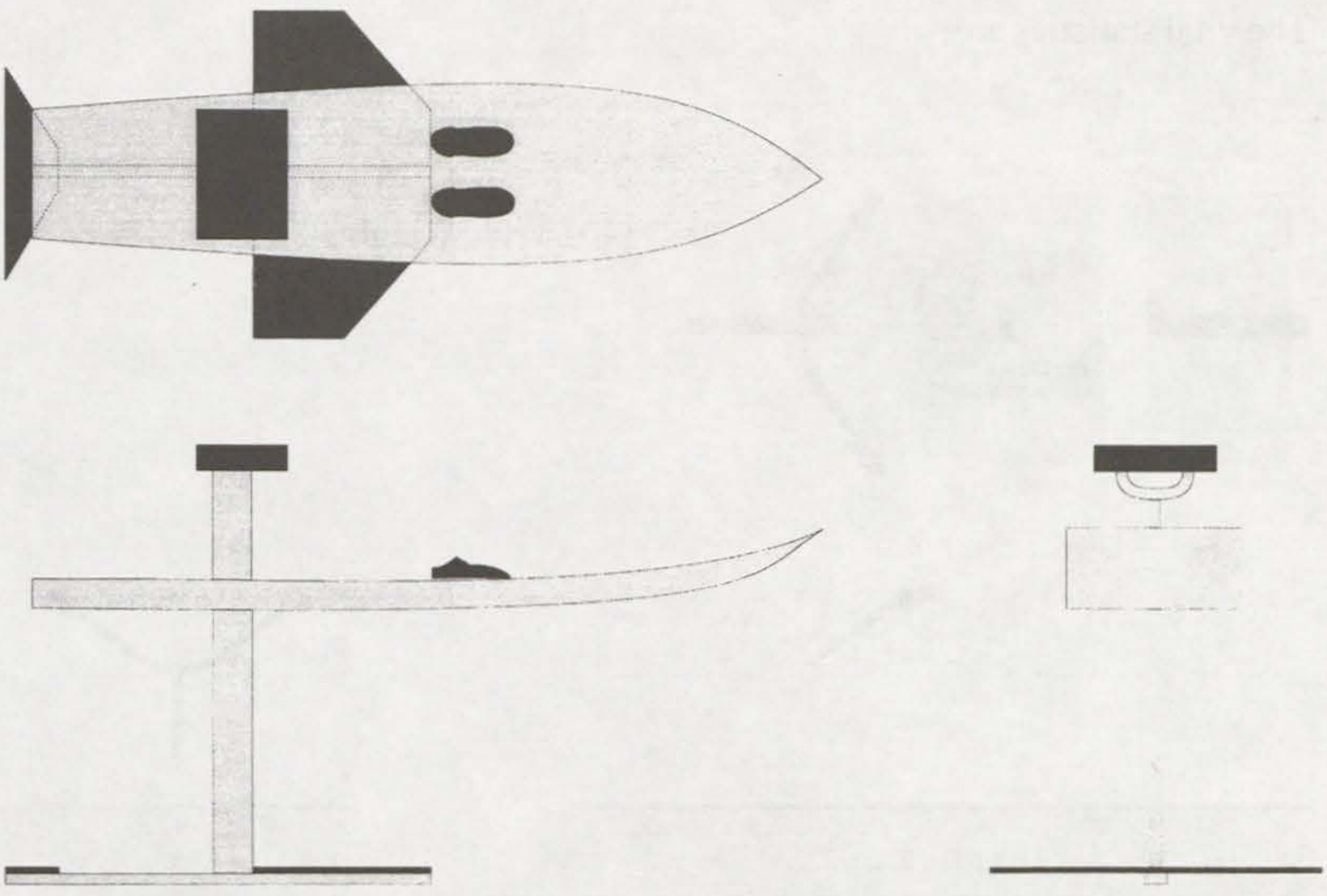
The Air Chair

Foil-borne Surf-Ski

by Tony Kitson

(from information supplied by Billy Roeseler)

The Air-Chair is designed to be towed behind a modestly powered RIB, Jetski,or anything with 15 hp. It will foil at 10-20 knots. The rider sits on the seat with his feet in the fitted retainers. Angle of attack is controlled both by the body position and the tow rope position. When the rope is lowered the angle of attack increases and you rise onto the foils. Get the angle too high and the craft takes off! It is said to be easy to learn the basics. Experienced pilots can perform advanced aerobatics.



Cory Roeseler has successfully ridden an Air-Chair towed by kite. David Culp suggests that Cory is probably the only person in the world capable of doing this. I would not argue with that! It occurs to me that, if the foils can be induced to pull down instead of push up, then you have a form of controllable hapa.

The Dynafoil 440

A Two-Point Foil-Borne Power Craft

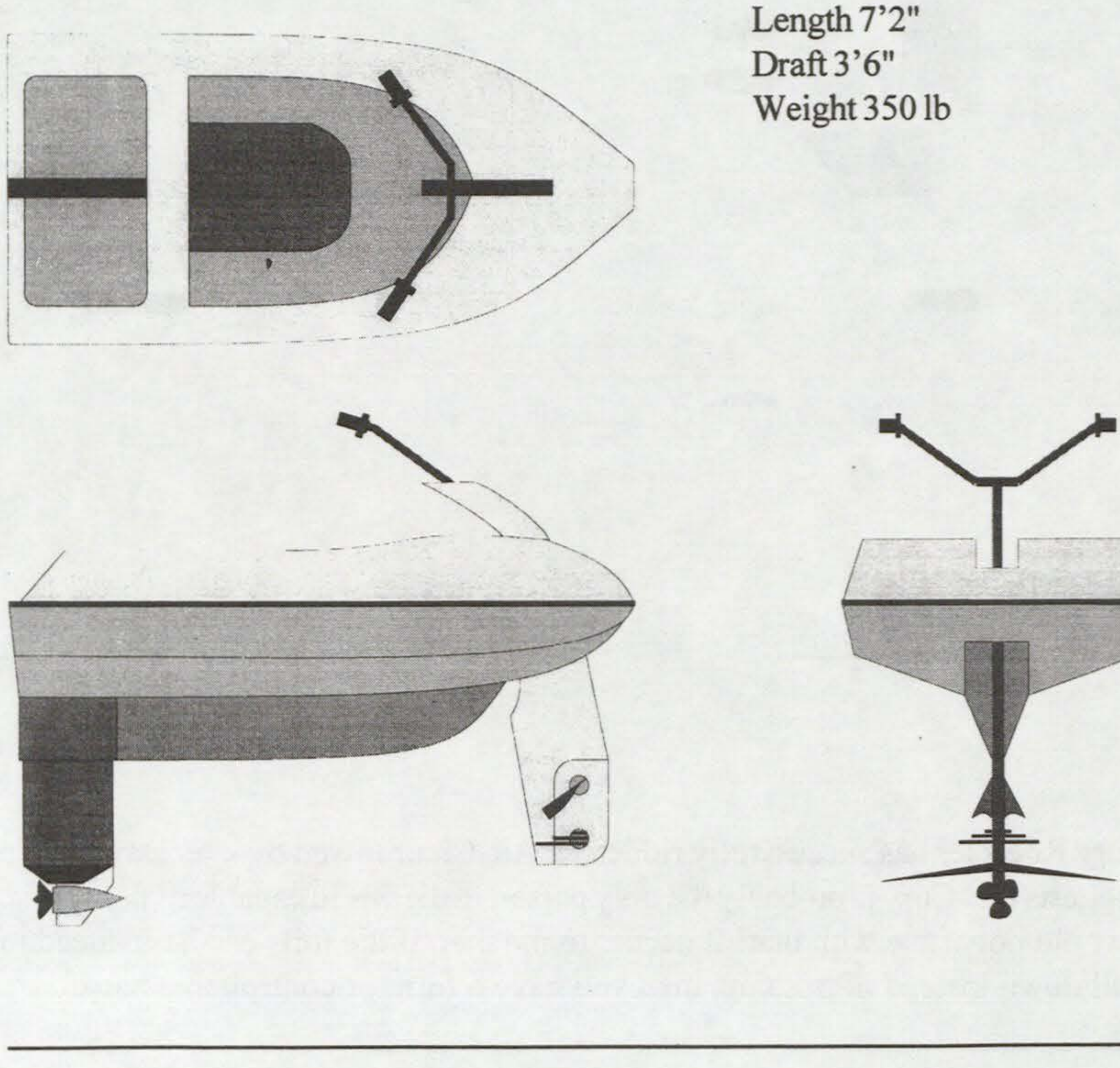
by Tony Kitson
(from information supplied by Billy Roeseler)

This is the craft that Billy Roeseler had originally intended to team up with the 'Big Bird' kite.

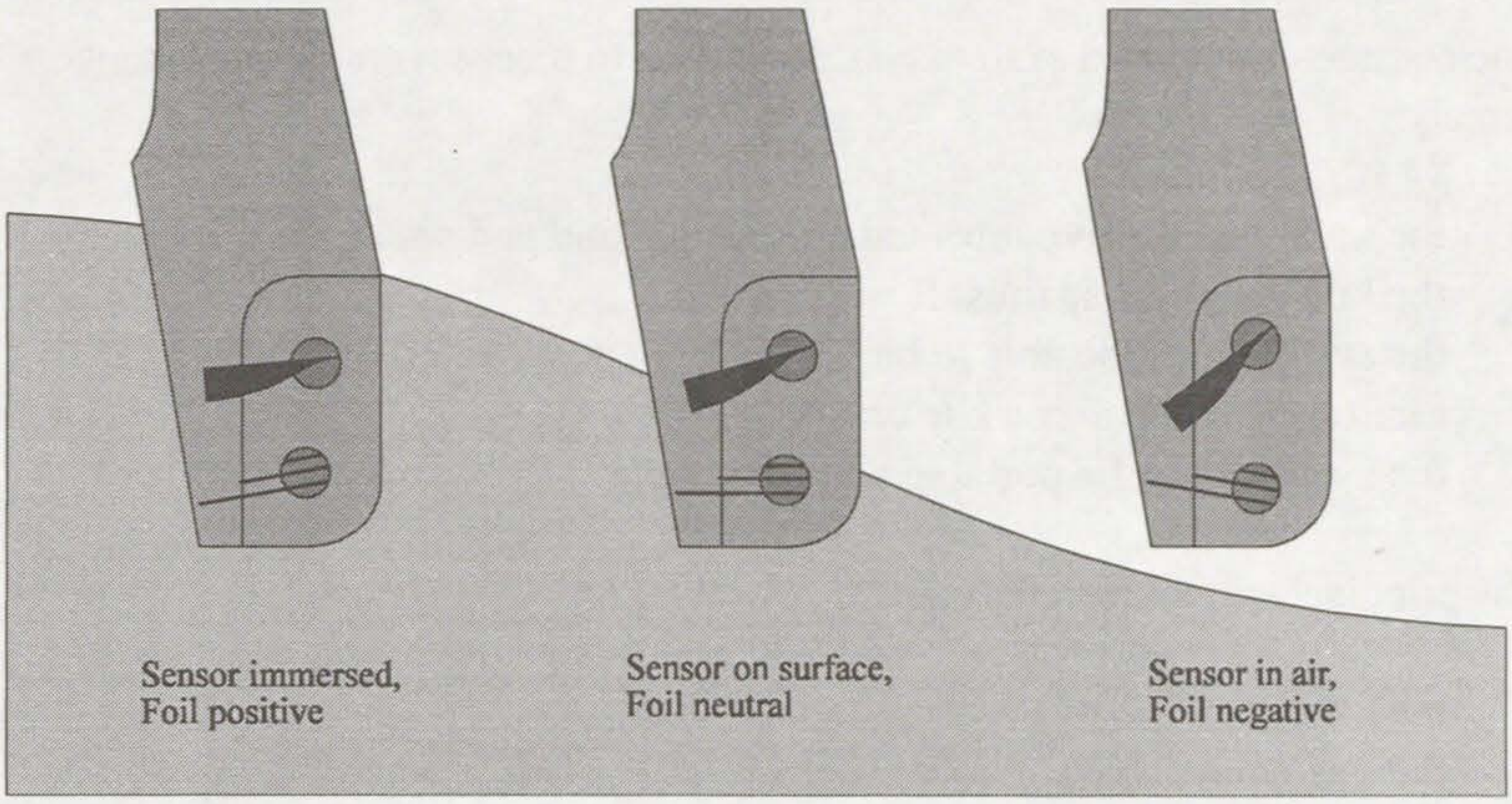
It is a two-point hydrofoil, molded in fibreglass. Both of the struts retract into the hull for ease of launching and recovery.

The vital statistics are:

36 hp motor
Length 7'2"
Draft 3'6"
Weight 350 lb



The front foils are surface-sensing, and may be of interest to foil-sailing readers. The principle of operation is shown in the diagram below. It is claimed that the stainless steel and nylon bearings require no maintenance and give 'millisecond response time'.



Dave Cline, Dynafoil, 881 W 16th Street, Newport Beach, California.

The Kiteski System

by Cory Roeseler

Condensed from an article written by Walter Giger for the Newsletter, following the talk and demonstration given by Cory and his wife, Terese, at the 1994 May meeting of the New England group.

The commercial Kiteski system was developed to meet several requirements, namely;

1. the kite must survive repeated crashes on land and water,
2. the kite and the skis must float on water,
3. the system must be able to be started from deep water, without assistance, even after a kite crash,
4. the system must be portable and affordable.

The principal system elements are;

1. the kite
2. the kite control bar,
3. the water skis.

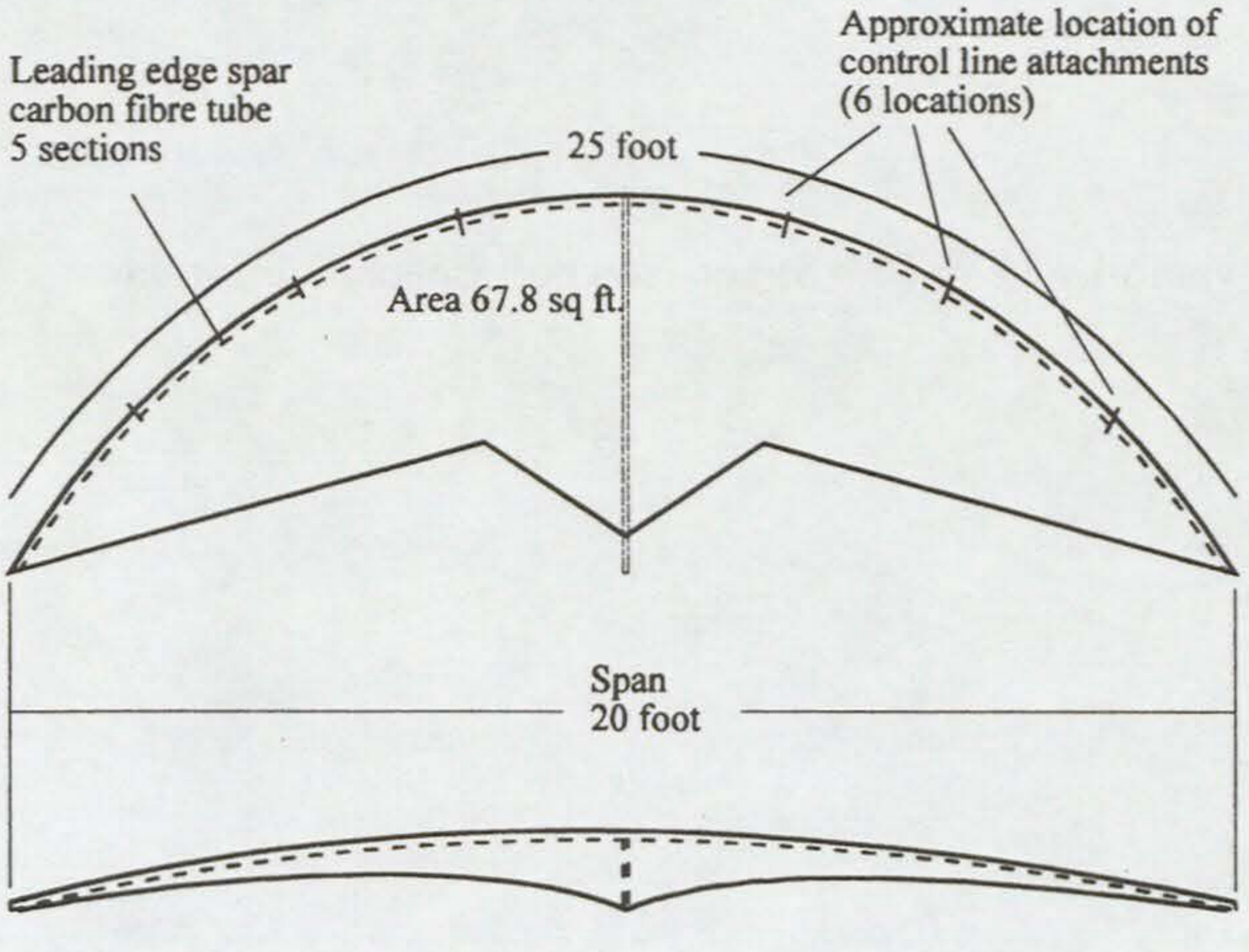


Figure 1. The Kite

The kite is shown in Figures 1 and 2. The kite is flying with slight anhedral and consists of a tubular, carbon fibre and epoxy composite, curved leading edge spar, with a single dacron skin. Two models are available with wingspans of 16' and 20' respectively and areas of 53.8 and 67.8 sq ft. Both kites weigh approximately 0.10 lb per sq ft of area.

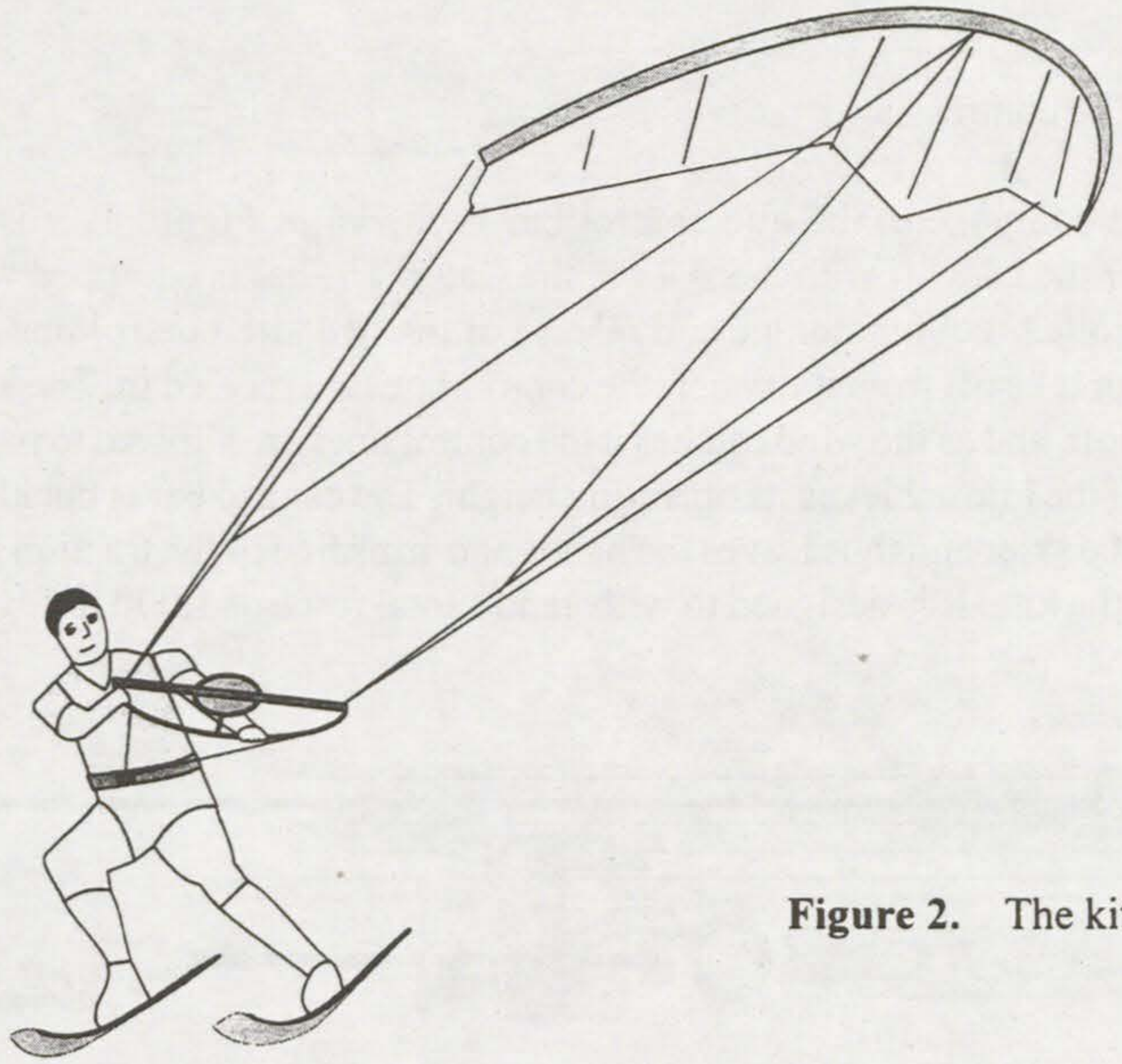


Figure 2. The kite in action.

The spar can be disassembled into five shorter tubular segments for ease of storage and shipping. The joints between the spar tubes are made by inserting short fibreglass tubes inside the carbon fibre tubes. Initially this lead to cracking of the ends of the carbon fibre tubes due to excessive hoop stresses. This problem was solved by wrapping linear glass fibre around the ends of the carbon tubes.

The leading edge spar provides a good handhold on the kite. This convenient handhold, combined with light weight, makes it possible for a skier in the water to hold the kite aloft and to achieve take off in the water at wind speeds as low as 10 mph.

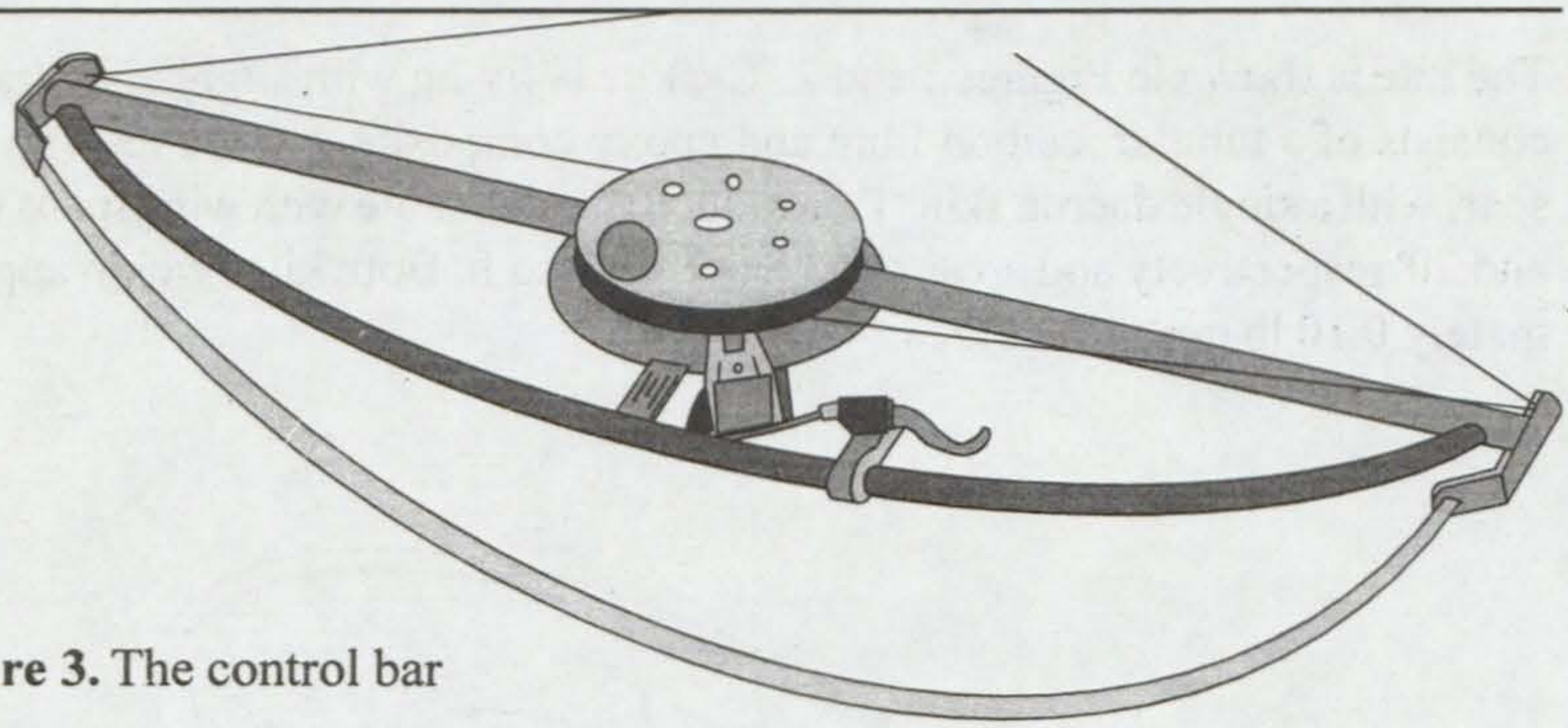


Figure 3. The control bar

The second component, the kite control bar is shown in Figure 3. It is also essential for the take off with the skier in the water. The bar is equipped with a brake-controlled reel for storage and release of the two kite-control lines, see Figure 4. For take off from the water, the control lines are reeeled in. The kite is then held aloft, and as the wind catches it the control lines are allowed to pay out slowly until the kite achieves its operating height. The control bar is buckled to the belt of the skier and thus leaves the hands and arms free of the traction force exerted by the kite. It is designed to withstand a total force of 1,000 lb.

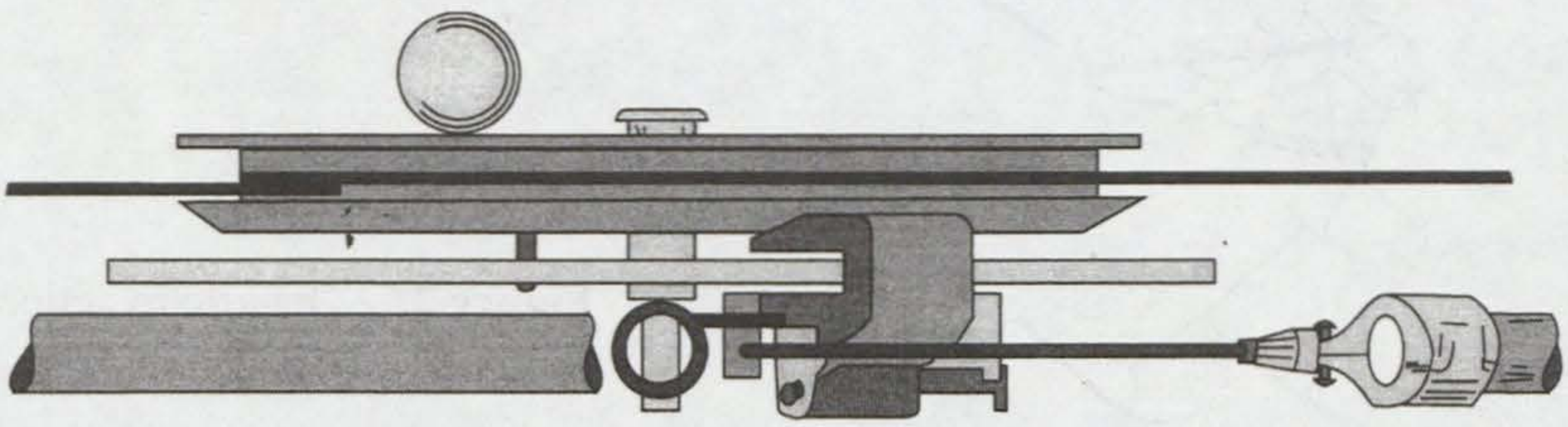


Figure 4. The reel and brake mechanism

The skis are 71" long and either 7.5" or 9" wide. In order for the kite to provide useful tractive force on a reach or sailing upwind the skis must generate a lateral force which is achieved by allowing the windward edge of the skis to cut deep into the water. It has been found that a small skeg is needed at the trailing edge of the ski in order to maintain control.

Figure 5 shows, on a polar diagram, the estimated speeds achievable for wind speeds of 10 knots through 30 knots. The highest speed capability is at about 120^0 off the true wind. At high speeds the problem is the physical control of the skis and the temporary loss of the lateral force as waves and the lift component of the kite's traction force raise the skier into the air.

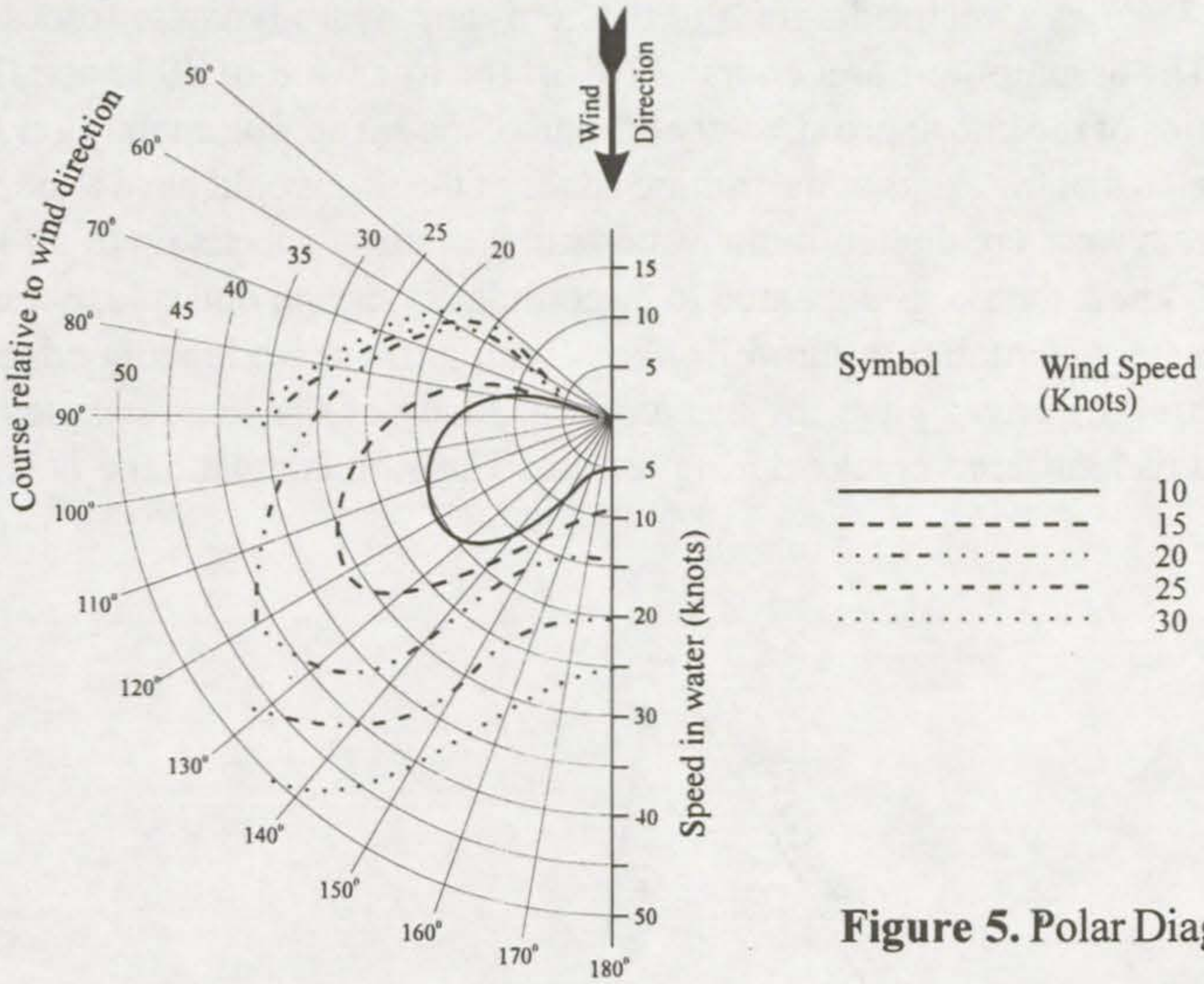


Figure 5. Polar Diagram

Cory Roeseler is aiming at achieving a world record speed of 50 knots with a wind speed of 40 knots. Drag estimates shown in Figure 6 indicate that a pair of water skis should have less drag at 50 knots than two of the previous speed contenders, namely Longshot and a surfboard.

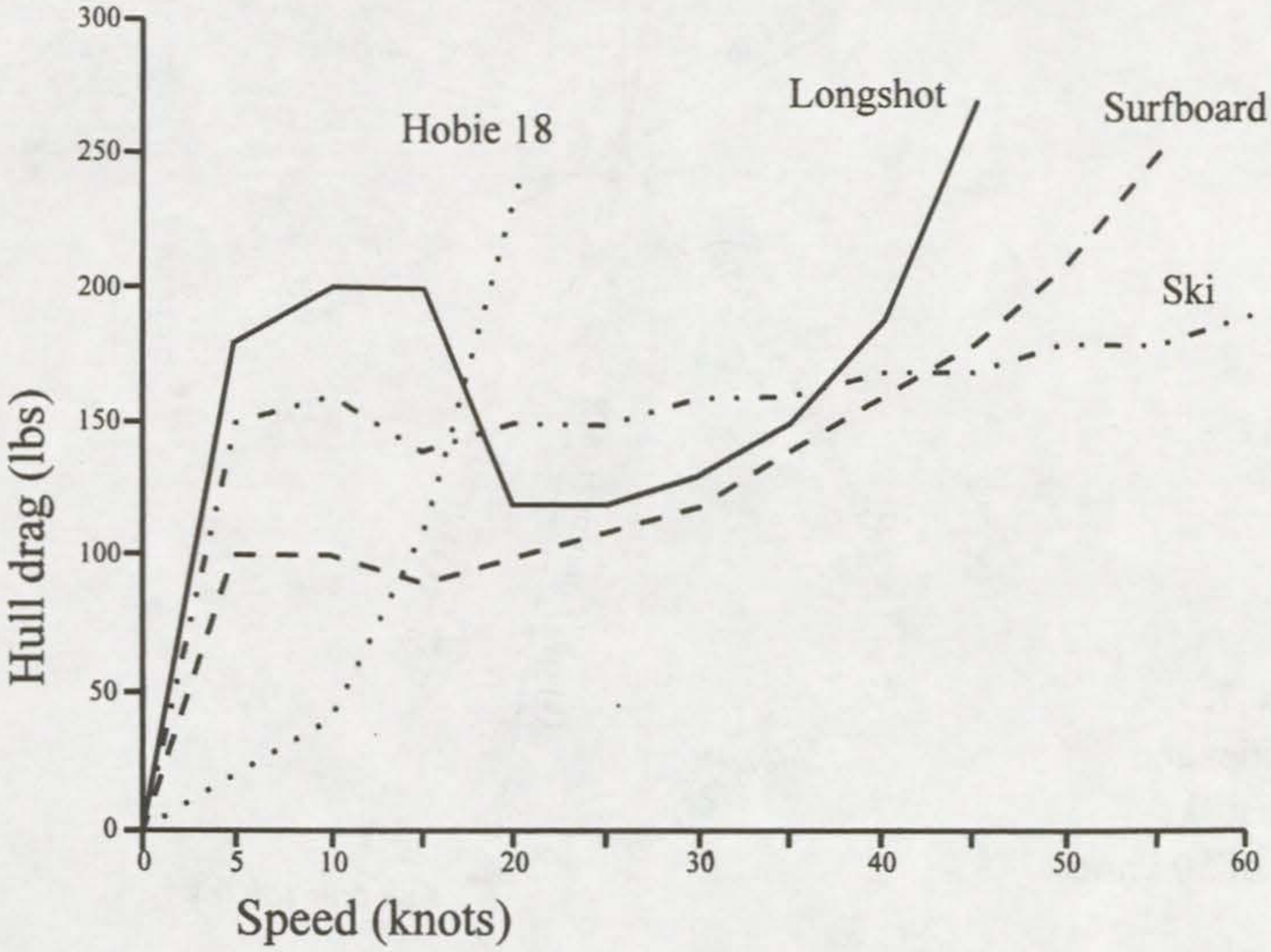


Figure 6. Comparison of hydraulic drag of different hulls

Figure 7 shows a vector diagram of the aero- and hydrodynamic forces at 50 knots. The assumptions are: course 120⁰ off the true wind of 40 knots; lift-to-drag ratios of the kite approximately 6:1 and of the ski approximately 1:1. Cory anticipated that the skegs at the trailing edges of the skis would have to be modified. Tests were conducted in the waterskiing mode at speeds up to 50 knots. Over 30 knots the skegs appeared to be completely dry on one side, not unlike a completely cavitating hydrofoil. Skegs with knife-sharp leading edges and square trailing edges gave the best control. Many of the skeg samples Cory showed had suffered cracks during testing. The strains must have been very large.

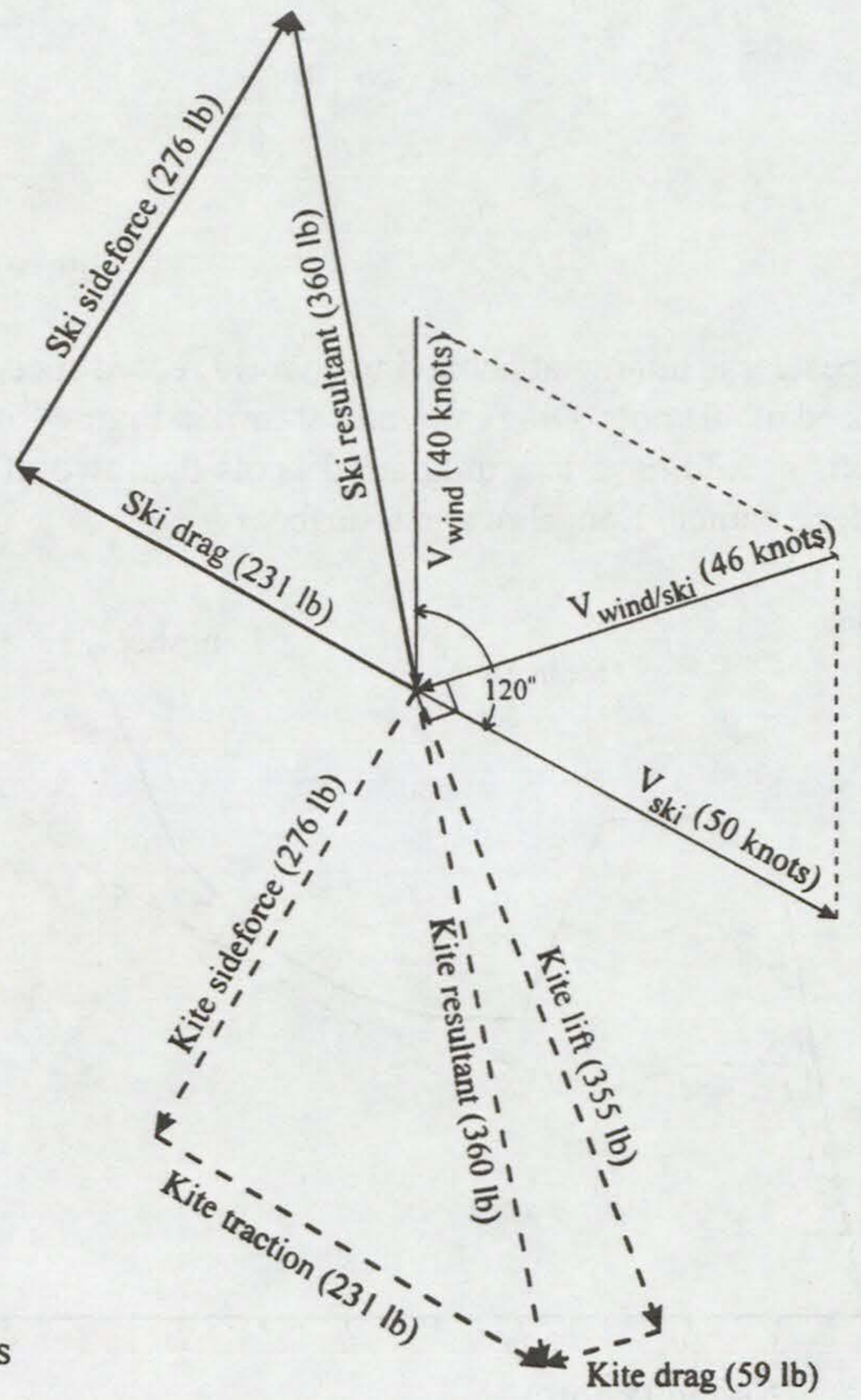


Figure 7. Velocities and forces at ski speed of 50 knots

Demonstration

After the talks at the meeting, Cory and Terese gave demonstrations of Kite-sailing. The wind was fairly steady at perhaps 15-18 knots. There were choppy waves perhaps 6 to 12 inches high. Performance was as "advertised", that is, spectacular. It was possible to play with the kite, bringing it close to the water for maximum drive or "parking" it high up. The kites were sometimes flown in figure eight patterns to increase the apparent wind speed. In-water launchers were repeatedly demonstrated. One of the kites had not been completely adjusted and was somewhat tricky to handle. The only down-side of this was that the wind and water were cold.

Summary

Clearly, the system Cory described is a maxi-min system. Through simplicity, persistent effort, analysis and creativity the performance enhancing factors have been maxixmised and everything else minimised or eliminated. Cory and the other developers have been very successful in meeting their design objectives.

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Introduction to Really High Speed Sailing

by Nelson Funston, Fred Gunther, Ron Jones and Billy Roeseler

Just 30 short years ago Bernard Smith shocked the world by suggesting that we could sail at 40 knots. Today several boardsailors and one hydrofoil have bettered that mark over a 500 metre timed course, and one wing sail craft has claimed bursts over 50 knots. In fact, anyone who is reasonably fit can, for a total investment of less than $2,000, sail 40 knots on a production Kiteski. While most of us will be content to stay below 40 knots for recreational and commercial sailing, there are always those few who would push the limits of sailing speeds. Land yachts are racing across the dry lakes of California and Nevada above 90 knots, and a few ice boats have exceeded 100 knots on glare ice in Wisconsin.

By combining elements from existing aeronautical and marine systems, it is now possible to sail on water above 200 knots. The basic concept for the ultimate sailboat was presented by two of the authors at a meeting with Bernard Smith and others in Pamona, California, in 1979. We suggested how towing a small hydrofoil with a modern sailplane could generate speeds of 40 knots in a 10 knot wind. The forum was the Ancient Interface Sailing Symposium, an annual meeting of members of the American Institute of Aeronautics and Astronautics and the Society of Naval Architects and Marine Engineers. The actual embodiment of these kitesailing principles has been somewhat different from that which we theorised in 1979, as we decided, for safety reasons, to leave the pilot near the water instead of in the air. The Kiteski is the embodiment of these principles, and it requires a wind of 30 knots to sail at 40 knots. The compromises that were necessary to get the unit into production at a retail price below $2,000, included reduction of L/D of the kite from 40 to 6 and reduction of L/D of the 'fish' from 40 to 3. We are using a modern two-line stunt kite instead of a high performance sailplane, and an ordinary water ski instead of a surface sensing hydrofoil.

Broad reaching at 40 knots in a 30 knot breeze gives a relative wind of 40 knots at an angle 45 degrees off the bow. Drag on the kite uses 10 degrees of that wind angle, and drag on the ski uses 20 degrees. The other 15 degrees are used by drag on the lines and the skier. We have not been able to make a lot of scientific measurements to prove all of this, but we have accumulated several hours of sailing experience above 20 knots, including at least 10 hours at above wind speed and an hour above 30 knots, mostly in the Columbia River Gorge.

The AYRS has done more than any other organisation to promote high speed sailing, and we were pleased to demonstrate the Kiteski at the spring meeting of the New England chapter in 1994. The wind was below 15 knots, so our speeds in Newport, RI, were below 20 knots, but the crowd seemed pleased with many aspects of the system.

Improvements in sailing speed will come when we can link more efficient kites to more efficient hulls. One of the nice things about kitesailing is that we can work on the sail problems almost independently of the hull problems. We know that sail efficiency as high as 50 is now achievable, and Nelson Funston enjoys that level every time he sails his open class sailplane over the thermals of Eastern Washington. We know that lateral resistance can be had above 100 knots on water, and Ron Jones gets over 10,000 lbs of it every time he puts one of his unlimited class hydroplanes into a turn in competition.

By combining the side-force/drag ratio of a modern hydroplane entering a turn at 200 knots with the side-force/drag ratio of a Reno Air Racer also entering a turn at 200 knots, we can imagine how a modern kite-boat might broad reach at 200 knots in a true wind of only 40 knots. The Reno Air Racers are derived from WW II fighter planes and achieve side-force/drag ratios above 10 at speeds from 200 to 300 knots at sea level. The modern hydroplanes feature high-strength steel skid fins which are ventilated to the surface and achieve side-force/drag ratios above 6 at speeds up to 200 knots. At 200 knots of boat speed in a true wind of 40 knots the apparent wind is about 16 degrees aft of the bow. At L/D of 10 the wing needs only 6 of those 16 degrees to keep pulling forward on the boat, and at L/D of 6 the boat needs the other 10 degrees to avoid slowing down.

The kitesailing principles needed to sail above 100 knots are well understood by several dozen people around the world. The only reason that we have not yet put these speeds on the clock is lack of funding. It is difficult enough to raise $100 million to challenge for the Americas' Cup, but there is sufficient status on that contest to make funding possible. There is relatively little status in high speed sailing, so even the best funded wing sail craft have probably consumed less than $1,000,000, and there has never been even £100,000 for kite powered craft. There is no doubt we could have an unlimited sailing speed record above 50 knots within one year if we had $100,000 to devote to this goal. For $1,000,000 we could exceed 100 knots. Getting 200 knots would cost more, as we would no doubt need to spend a lot of time waiting for the wind to blow 40 knots while we have the clocks set up.

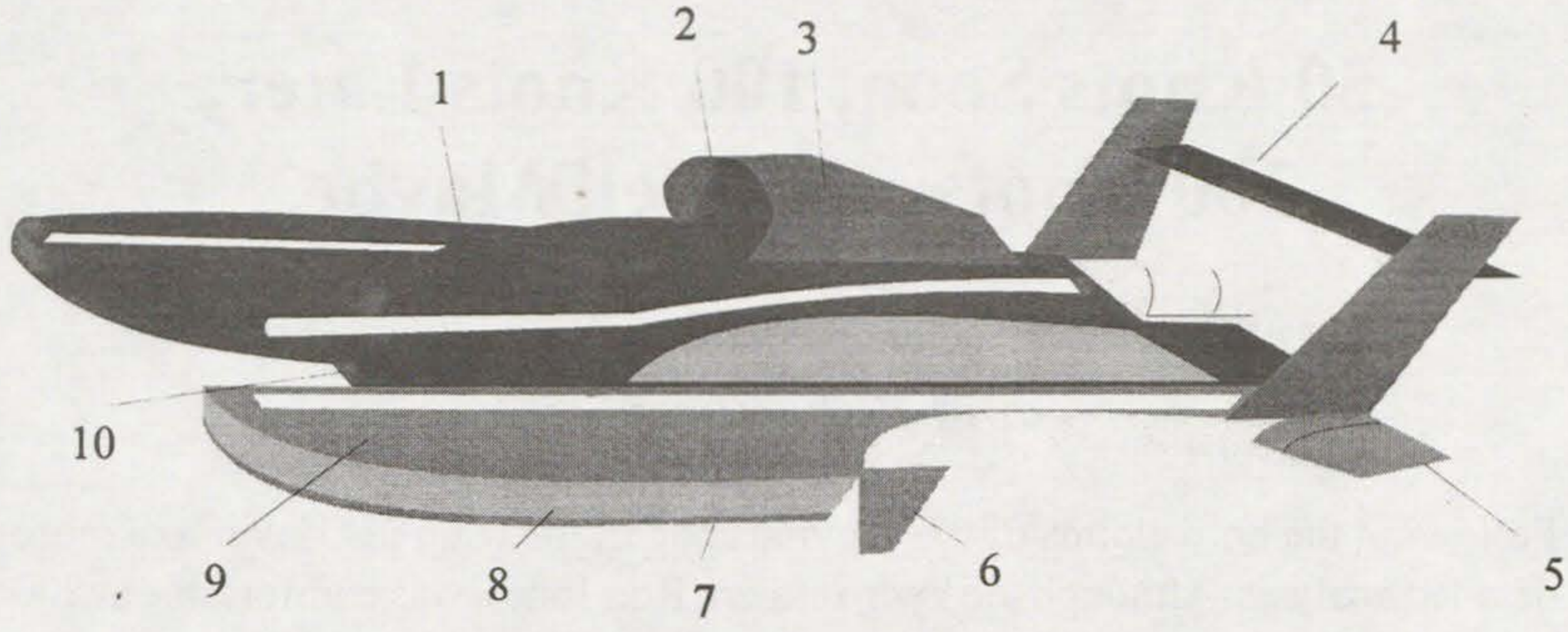
The primary market for commercial sailing craft is below 20 knots, so there is little motivation within the shipping industry to sail above 100 knots. We can only hope that some day there will be sufficient interest in high speed sailing that we can put together a programme to achieve some of the goals discussed in this paper.

With recent advances in sailing technology, materials, flight controls, and hydrodynamics, it now appears to be feasible to sail at speeds up to 100 knots in moderate winds. We have learnt how to operate power boats at speeds up to 200 knots, and to get these boats around a two mile course at speeds well over 100 knots, using high strength steel 'skid fins' to generate well over 10,000 lbs of lateral resistance in the turns. We have also learnt how to build light-weight sailplanes capable of extracting over 100 horsepower from available summertime winds. Sailing at 100 knots in comfort and safety will require little more than combining the aerodynamic efficiency of a modern sailplane with the hydrodynamic efficiency of a modern hydroplane, and a man-rated capsule to protect the driver in the event of a crash. The Kiteski has already demonstrated the ease of controlling a kite and high-speed planing hull at speeds up to 40 knots. We may borrow the radio link and low-cost autopilot from radio control modellers to augment the performance and stability of the 100 knot sailing system.

Let us now review the basic elements of high speed sailing:

Wind. The fuel for all sailcraft is the wind, which can turn from a gentle friend to a cruel master in a storm. We are not proposing to measure sailing performance in a hurricane or typhoon where any solid object may be propelled at well over 100 knots. The current sailing speed record of 46 knots is held by the wing sailed craft, 'Yellow Pages Endeavour', sailing in only 20 knots of wind. We are proposing a sailcraft somewhat safer and more seaworthy than YP, that will safely handle gusty winds of up to 40-50 knots. We have already demonstrated the safety and stability of the Kiteski in the Columbia River Gorge under these conditions. The perfect balance of the kite sailing system allows us to use compact hulls that provide reasonable comfort at high speed, even with moderately high waves.

Sail. The proposed sail is a rigid airfoil of 50 ft span and 3 ft chord, weighing less than 200 lbs, and capable of extracting 200 hp from a 40 knot wind when attached to a moving buggy, sled or boat which is moving across the wind at 100 knots. The wing is controlled by a suitable tail surface with conventional rudder and elevator, which in turn are driven by servo motors. Flying 100 knots in a 40 knot wind produces a relative wind of 108 knots at 22 degrees off the nose. At a lift coefficient of 0.5 this sail will develop $C_L qS = 3{,}000$ lb, which will support the 200 lb flying weight if inclined only about 4 degrees from flying on the edge. With a L/D ratio of 20, the sail uses only 57.3/20 = 3 degrees of our available 22 degree wind angle, leaving 19 degrees for water drag and windage on the hull and tether.



American Power Boat Association's Unlimited Class Hydroplane

1.	*Cockpit (fully enclosed safety capsule)*	*2.*	*Airscoop (air intake for engine)*
3.	*Engine (Lycoming turbine)*	*4.*	*Tail Fin Assembly*
5.	*Tiplets (to lift transom, avoid bow lift)*	*6.*	*Skid Fin (provides side thrust for turns)*
7.	*Runner (bottom surface of sponson)*	*8.*	*Non-Trip Chine*
9.	*Sponson*	*10.*	*Canard (for bow up/down control)*

Hull. The hull is derived from a D stock hydroplane, which will run 100 knots using power from a stock 170 cubic inch Falcon car engine, which puts less than 100 hp into thrust, after considering the losses due to propeller efficiency. The latest carbon/epoxy hydroplanes weigh less than 200 lb empty and provide reasonable comfort for a 200 lb driver up to 100 knots. The only modification to adapt an existing hydroplane for kite power would be to replace the propeller and shaft with a suitable planing surface aft, that will keep the boat at the correct pitch angle for most efficient three point planing. At 100 knots, the drag on the 400 lb craft without lateral resistance is less than 100 lbs and that would consume only 170 x 100 / 550 = 30 hp, of the 200 hp available from the sail. That means we have 170 hp, or slightly over 600 lb of thrust available to overcome the drag on the keel or 'skid fin' which must be providing nearly 3,000 lb of lateral resistance.

The key to making all of this work is to keep the drag on the skid fin below 600 lb, which will require an L/D of 3,000/600 = 5. Stock skid fins have an L/D = 3, and we think that we can get 6 by using a slightly higher aspect ratio.

Checking the energy balance, we have a tether pulling 3,000 lb, 150 lb forward on the kite and 3,000/5 = 600 lb forward on the hull. This system appears to be in balance beam reaching at 100 knots in 40 knots of wind. Of course we are anxious to get out on the water to try it.

Any takers?

50 Knots Soon, 100 Knots Later, 200 Knots .... Well Maybe.

by Nelson Funston, Fred Gunther, Ron Jones and Billy Roeseler

Following the bold claims of the previous paper, the team got down to a more detailed analysis. Although the hydro expert, Ron Jones, was comfortable at 200 knots, the aero expert, Nelson Funston, urged us to consider 100 knots in more detail. Nelson spent the summer in his Nimbus 3 sailplane, soaring the skies of Eastern Washington around 100 knots, ticking off 300 mile triangular courses like they were pieces of cake, using a tow to 3,000 ft above ground level from a powered aircraft to get started, then relying on atmospheric 'lift' to get around the various courses. 'Landing out' was rare, as he was almost always able to plan the flight to take advantage of thermals to get high enough often enough to get back to the airport, without the need of his trailer equipped ground crew to drive out and pick him up. If there was a good strong thermal 50-80 miles out, he might stay in it for up to ten minutes by circling, then exit at cloud base, say 10,000 ft, and use his 50:1 glide slope to complete the task in one steady pass, whooshing through the exit gate at 100 to 120 knots at 3,000 ft above his home field at Ephrata, then pulling up, going around, setting up an approach 1/2 mile downwind of the runway, and using speed brakes to make a perfect landing within 100 yds of his ground crew.

Ron spent his summer building hydros for the active limited and unlimited fleets, which race throughout the Midwest and West at speeds between 100 and 200 kts. One of the most important parts of a hydroplane is the skid fin, which allows it to pull up to 1.5 g's in the turns, and consumes up to 600 hp. Consider an unlimited hydro weighing 6,000 lbs, which must develop 9,000 lbs of lateral resistance to negotiate a 1,000 ft radius turn at 130 knots = 220 ft/sec. The radial acceleration is $V^2/R = 220^2/1000 = 2.2 \times 22 = 48$ ft/sec^2 = 1.5 g.

Ron tells us that the hydro might enter the turn at 150 kts, but slow to 110 knots, even at full throttle, prior to completing a 180 degree turn, which takes about 14 seconds. If prop efficiency is 65%, the thrust is around 3,000 lbs, so there must be over 1,000 lbs of drag on the skid fin to slow the boat at 0.18 g. The average deceleration during the 14 seconds turn is 5 ft/sec^2, as we lose 68 ft/sec in 14 seconds. With little skid fin drag in the straightaway, the hydro is able to accelerate at 0.18 g for 14 seconds to get back close to 150 knots prior to the next 180 degree turn. With two turns and two straightaways, the hydro completes the 12,000 ft oval course in 56 seconds, at an average speed of 220 ft/sec = 150 mph = 130 knots.

That makes the L/D on the skid fin less than 9,000/1,080 = 8, and there lies the key to sailing really fast. With many wings able to deliver L/D > 30, but no hydrofoils above 8 at 100 knots, we should really spend most of our time and energy looking at means of developing lateral resistance. Fred Gunther then points out that it is not just lateral resistance, but lift and lateral resistance, if the water part of our system is to overcome the force of gravity on the pilot and his safety capsule. The test is to measure tow line angle from dead astern as the 'fish' is towed out to the side of a power boat in various wind and sea conditions.

We started with Kiteski, which is reasonably safe and controllable in the speed range from 10 to 40 knots. The best tow line angles were around 50 degrees at speeds of 20-30 knots, which indicates an L/D greater than 3 for conventional water skis. At 45 degrees, drag equals side force, and we got 100 lbs of each with a 200 lb (gross weight) skier and 300 lb ski force. The tow line force was 150 lbs.

Next we tried a model foil born trimaran, which made use of high aspect ratio (3:1) surface piercing foils to achieve a tow line angle of 70 degrees, side force = 100 lbs, drag = 20 lbs. Since the model was nearly weightless, the total foil force was 100 lbs and the L/D was 5. The low aspect ratio submerged foil on the Air Chair was also able to generate a tow line angle of 70 degrees, with a side force of 200 lbs, drag = 40 lbs, lift = 300 lbs, L/D = 8, at speeds between 10 and 20 knots.

Cory reports from the Gorge that Mike Murphy, the world's best Air Chair pilot, is now in control of our 20 ft kite, and is giving the sailboards a run for their money on all points of sailing, making up to 3 x wind speed in a mild chop in 10-12 knots of wind. He is taking three kites back to Southern California to add the challenge of kite power to his growing world wide customer base of nearly 10,000 Air Chair pilots.

The last run of the Blowout, the 20 mile downwinder in the Columbia River Gorge, pitted 40 of the best sailboarders against the Kiteski, which still holds the record for the course of 56 minutes set in 1989. This year 7 sailboards managed to keep up with the Kiteski, which averaged 30 knots over the water in

15 knots of wind for the first 12 miles. These seven also finished up 20 minutes ahead of Kiteski, as Cory lost his balance on one ski and broke a line while restarting. The message is that the 15 inch fins on the boards generate lateral resistance twice as efficiently as the Kiteski at 30 knots, and we will need to improve our L/D = 3 in the water if we are to continue to win races in moderate wind conditions. We are not competitive at all to windward, with the sailboards now making 10 knots good to windward in 20 knots wind, and Kiteski barely able to make 5 knots.

This little digression from the 100 knot exercise is needed to put the skid fin into perspective. We have started testing skid fins on a little 10 ft hydroplane capable of running over 40 knots on a 10 hp engine. By clocking our time around a 1200 ft oval here on Juanita Bay with various skid fins, we can dial in the one that makes the most sense for a world record run at 50 knots at a speed course at Lysle, WA.

Ron Jones tells us that the best skid fins at 100-200 knots are less than 6% thick and have an aspect ratio of 1. They are loaded above 10,000 lb/ft^2. When he tried higher aspect ratios, hydroelastic effects caused the inboard sponson to lift in the turn, so they went back to flat steel plates with sharpened leading edges, blunt trailing edges and much more thickness above the waterline.

Our first trial fin on the 10 ft hydro had only 10 in^2 area, and at 20 knots, which was all we could get from our stock 8 hp Nissan dinghy motor, we got so little side force that we could not even tell that the fin was there. (We should have checked $q = rho\ V^2/2 = 34^2 = 1000$ psf. The maximum load possible on 10 in^2 would be less than 100 lbs, and the gross weight was over 400 lbs.)

We now have a Yamato 80 racing motor, capable of pushing our 10 ft hydroplane above 50 knots, where we should be able to get close to 1 g side load from 10 in^2. We will try different areas, aspect ratios, thickness/chord ratios, and twist until we optimise our time around the 1200 ft oval.

The intention is to prove the concept by sailing the 10 ft hydro with a stock Kiteski wing. We expect that this configuration should be capable of around 50 knots on a good day on the Lysle course in 30 knots of gusty wind. The achievement will be all the greater because it will not require the athletic ability which Cory must employ on the standard Kiteski. We believe that Fred Gunther's buddies at the Yacht Club will be far more impressed to see a middle aged couch potato like me and a spunky old man like Fred scoot past their $100,000 race boats, being towed by a 20 ft kite!

Having achieved whatever success we may, on our own limited resources, with an antique wooden hydroplane and a stock Kiteski wing, we might then try to get some funding so Nelson and Ron could take over with much better wings and much larger boats, and perhaps have a go at sailing 100 kts.

Correspondence

between Billy Roeseler and Tony Kitson

I am particularly excited about your experiments with fins, let me know if you have any other material on this. I have spoken with Ian Hannay regarding the effectiveness of the fins used by the powerboats. He injects a note of caution. Apparently the onset of cavitation at high speeds is not immediate. I understand from Ian that there is a delay between the moment that high side thrust is begun and the onset of cavitation. He wonders whether the powerboat guys are taking advantage of this fact. Their requirement for high side thrust is limited to only a brief period and they may not be holding it long enough to encounter the problems. However, there is clearly a lot that is not fully understood in this area, I understand that tank testing of the Longshot foils predicted failure around 37 knots, but in practice they held up for higher speeds on the craft. I think that the work you are doing with your towing tests will be most valuable.

First on the subject of transient phenomena for foils. As far as I know, none of the power boats are taking advantage, if it indeed exists. The main reason is that these are all ventilated to the surface, and what might be true for deep submergence is not necessarily relevant to a ventilated foil. Even if it was available, the power boats would not likely take advantage, because it could impair control of a marginally controllable craft. The power boat community are seat-of-the-pants scientists, with very little money for tunnel tests, but we are very serious about our sport, and many have given their lives pushing the craft to higher speeds. Even if we could get a 10% improvement in L/D by keeping air from the suction side of the foil, we would not be able to predict when and if we might suddenly lose it. We would not want to take advantage of it, as it might cause a crash when we lost it.

One question about your tests, how are you managing the towing and drag angle measurement? I had some thoughts about this type of tow testing myself but was concerned about the towing vessel. I thought that I would need a vessel that would be both very fast and have a very firm grip on the water, to avoid it making leeway. A typical speedboat or RIB will surely be most susceptable to a turning moment from the tow line and thus the angle measured between the tow and the fore and aft axis of the tow craft would not be an accurate measure of drag angle. Strictly I guess that you need to measure the angle between the tow line and direction of motion of the towed craft. This is obviously very difficult to achieve and, provided the two craft are running parallel, you could measure the angle between the tow line and the direction of motion of the towing craft. However this is still difficult if the direction of motion is not the same as the fore and aft centreline of the craft.

Second, on the subject of L/D measurements of foils towed behind power boats. Our favourite tow boat is a 19 ft tournament boat. These tournament boats are designed to tow a water skier through a slalom course at 36 mph and are equipped with one or more ventral fins and a rudder to achieve ease of control with a skier pulling up to 1,000 lbs of side force as he rounds the buoys on the course. The fins have span and chord of around 6 inches and are fixed to the keel amidships. Incidentally, they are not ventilated, so any transient flow characteristic mentioned in the previous paragraph is probably in effect for these fins, but we have no way of measuring it. These boats weigh less than 3,000 lbs fully loaded with gas, driver and one or more observers, and have a top speed around 40 mph with a 250 hp marine engine. Towing angles measured on these boats are probably accurate to within 5 degrees, as the boats track very well in their designed speed range from 20 to 30 knots.

For higher speed testing we used a 19 ft tunnel boat with a 135 hp outboard, and a 17 ft deep-V boat with 150 hp outboard. Both of these boats weighed less than 2,000 lbs fully loaded, and they were difficult to control in the slalom course with a 200 lb skier pulling up to 1,000 lbs side force. Their top speed was around 50 mph, and the probable error in line angle was around 10 degrees. All of our tow boats are equipped with towing pylons well forward of the stern, so the line angle can be compared to marks on the gunwhale to estimate tow angle. We did not make corrections for leeway of the craft, although this could be done in the future. The deep-V boat probably had more leeway than the tunnel boat, both would have about twice as much as the tournament boat. For side forces below 200 lbs at speeds above 30 knots, the leeway on these boats was insignificant.

We do not have access to big boats capable of speeds in excess of 60 mph, so we are looking forward to starting our tests with the little wooden hydroplane next week. The bay just a quarter of a mile from my house is usually calm in the morning and I can put out some marks to drive around to define an oval course of around 1200 ft, about 10% of what the 200 mph unlimited hydros use. By clocking my time with a stop watch, I should be able to get an idea of the relative efficiency of the various skid fins that I will be testing. We should be able to get a hundred data points this year at a cost no more than $1,000. Going to the MIT water tunnel like Longshot did would add several orders of magnitude to the cost. Of course, there is an element of risk, and my time may be worth several orders of magnitude more than the boat, motor and materials. We will also need a rescue boat standing by in case of difficulty on the course.

I hope that the Kiteski enterprise is prospering. Cory's demonstration to the New England group was very well received. Have you any plans for another visit to the UK or Europe? I have not yet seen a Kiteski or Banshee in the UK, I keep hoping. I am interested in the Air Chair used with kites. It occurs to me that, in the absence of anyone actually achieving Hagedoorn's dream, this is the nearest anyone has got. When using the Air Chair with a kite do you angle the seat away from the kiteline as with skis, ie use the foil as it is used with a tow boat? Would it be possible to strap the pilot onto the chair and use the foils in the opposite direction, ie incline the seat with the tow line and have the foils pulling down into the water? In this way you would be achieving exactly the dynamics planned by Hagedoorn. I guess you would need a bigger kite because all vertical lift of pilot weight would have to come from the kite, plus a bit to counter the downward pull from the foils. Could it work?

As for the Air Chair and Hagedoorn's dream, I hope Mike Murphy will be at the Extreme Games in Newport RI in late June. In light air Mike will be able to sail past any of the best sailboards that show up, and in heavy air Cory will do it on a production Kiteski. One never knows in advance what the weather will be, but we are very excited about this opportunity to promote concepts in high speed sailing. Our Sea Nymph concept disclosed at the Ancient Interface in 1979 also featured a pilot supported by air forces, with the water foil strictly for lateral resistance. We have found it more practical to support the pilot using water forces, as it tends to mitigate the consequences of a crash. All of our high speed sail craft are designed with crashworthiness in mind. We think that Yellow Pages is a bit risky for sailors.

Sailing Airships at Sea

by CP Burgess

Summary

It is possible to sail an airship at sea by means of lines attached to a small boat fitted with a hydrovane to resist leeway, while the airship is itself the sail which propels the boat. On some points of sailing, speeds over the water in excess of the true wind velocity are attainable; and it is possible to work to windward slowly.

Taking advantage of the wind to sail an airship without expenditure of fuel should be an advantage on patrol duty.

The Boat

A suggested form of the airship's boat may be described as a compromise between a seaplane float and a canoe. The midship section is shown in Figure 1. Leeway is resisted by a hydrovane on a strut on the windward side. Tacking is provided for by making the boat double-ended so that it may be towed in either direction, and the same side is always to windward. In this respect it resembles a Malay proa.

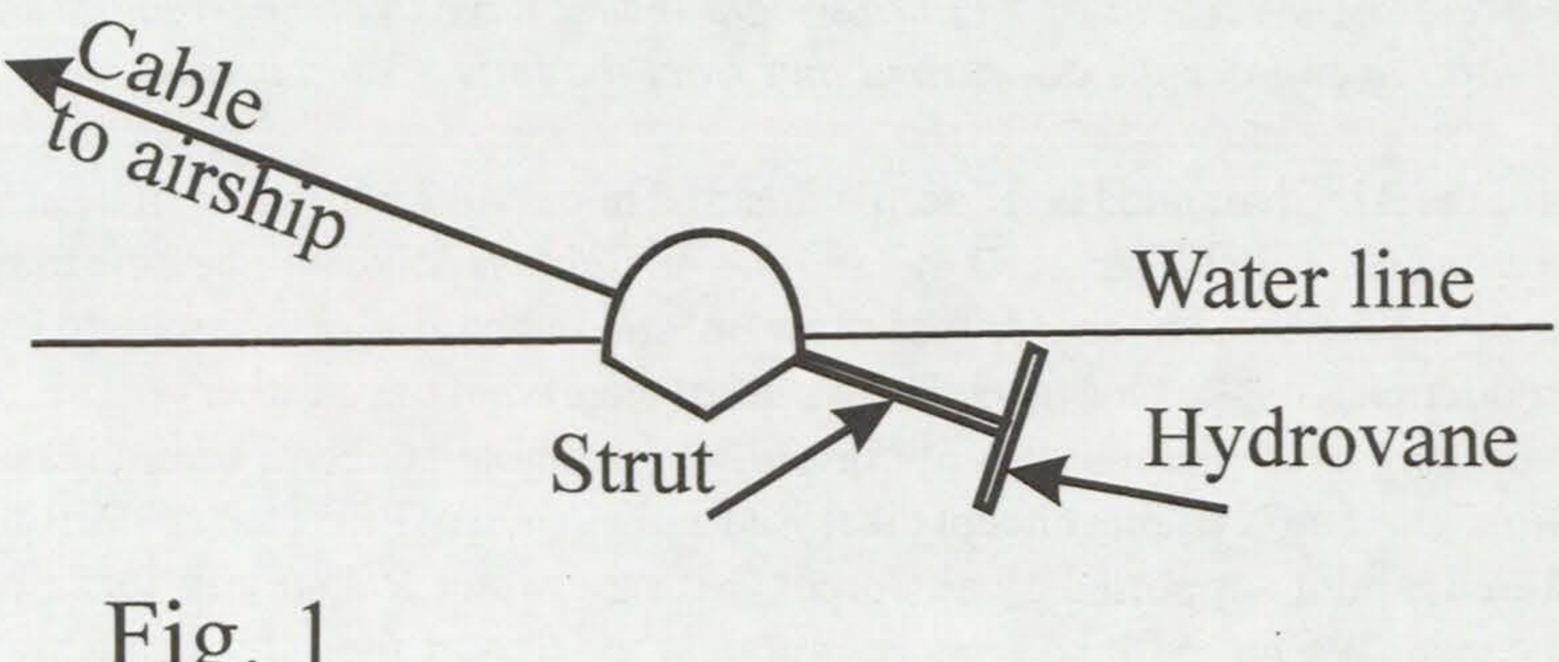


Fig. 1

The boat is virtually a sailboat in which the force exerted by the connecting cables to the airship is substituted for wind pressure on the sails. The magnitude of the wind force which can be applied to a sailboat is limited by the lateral stability of the boat to resist the heeling moment of the transverse component of the force acting at a considerable height above the centre of lateral resistance in the water. The airship's boat has the great advantage over a sailboat that the cable force can be made to act approximately through the centre of lateral resitance, as indicated in Figure 1, thus nearly eliminating the heeling moment, and permitting relatively much greater force to be applied, and much greater speed through the water to be attained. On the other hand, there is the disadvantage that the airship is a less efficient airfoil than a sail, i.e. the L/D is lower.

The boat should be heavy enough to avoid jumping out of the water, and have enough reserve buoyancy to prevent being towed under. How much weight and reserve buoyancy are necessary can hardly be determined in any other way than by experiment. They will undoubedly depend to a large extent upon the constancy with which the airship's altitude can be maintained, so as to avoid large fluctuations in the inclination of the towing cable to the horizontal.

Minimum Inclination of Course to Apparent Wind.

The close-windedness of the airship and boat combination, or the minimum angle which the course made good over the water makes with the apparent wind, depends upon the L/D of both the airship and the boat. By the L/D of the airship is meant the ratio of cross-wind to down-wind force transmitted by the airship to the boat (i.e. it includes the windage of the cables between airship and boat). For the boat, the symbols T and F will be substituted for L and D, respectively, T being the horizontal component of the water pressure force perpendicular to the direction of advance, and F the component in the direction of advance. Because of leeway, these directions will not be quite perpendicular and parallel to the longitudinal axis of the boat.

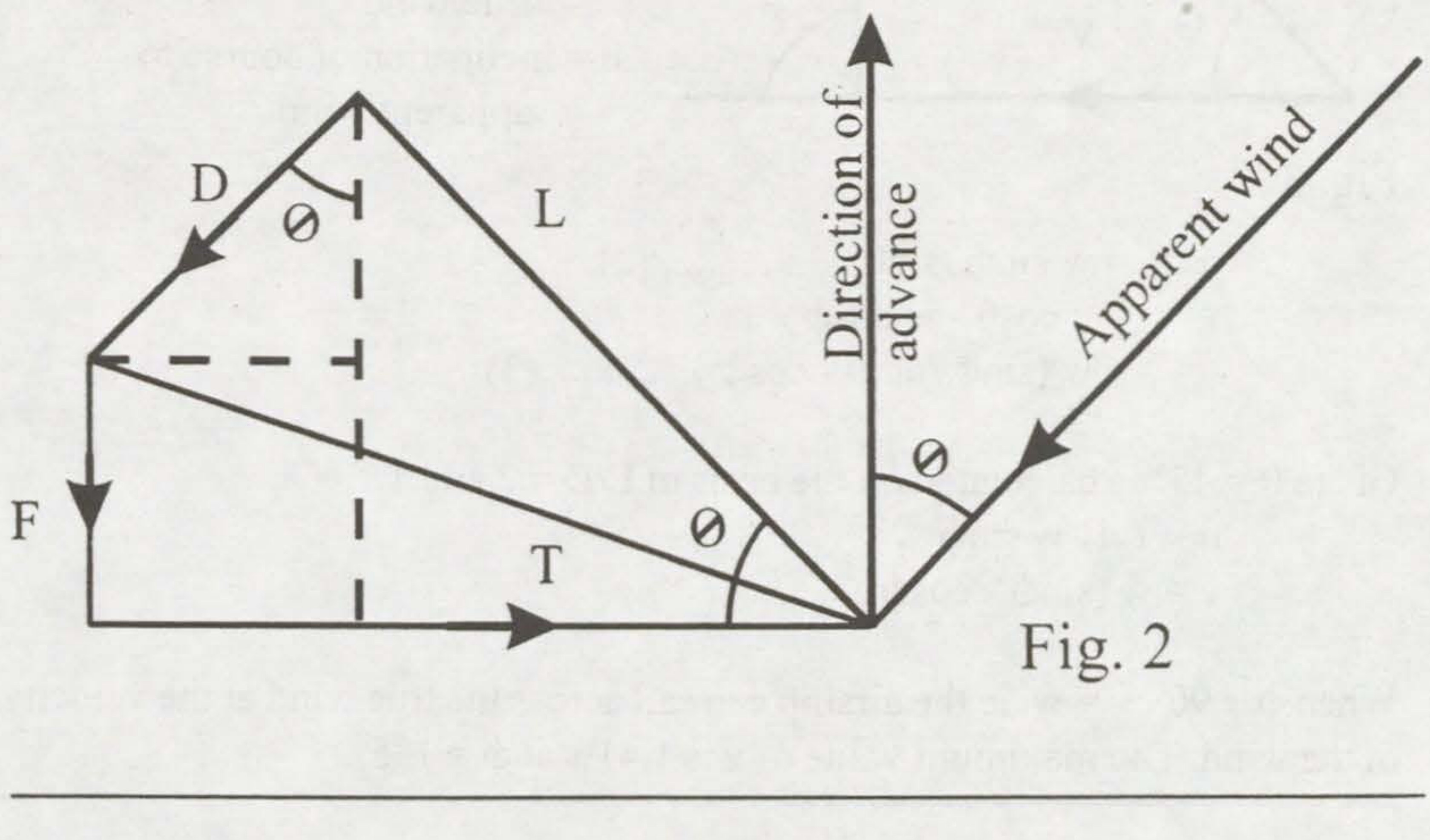


Fig. 2

It is obvious that the resultant of T and F must be equal and opposite to that of L and D. Let θ be the angle between the direction of advance and the apparent wind. From Figure 2 the following relations are deduced:

$$\left.\begin{aligned} T &= L\cos\theta + D\sin\theta \\ F &= L\sin\theta - D\cos\theta \end{aligned}\right\} \quad ....(1)$$

Given L/D and T/F, θ can be computed from these equations.

From wind tunnel data on the lift and drag coefficients of airships, and with allowance for the windage of the cables, it is conservatively assumed that L/D = 2.0. It is difficult to estimate T/F. The hydrovane should be quite efficient, but the boat itself represents pure drag of uncertain magnitude which varies greatly with the condition of the sea and the course with respect to the true wind. It is believed the T/F = 3 is a conservative assumption for preliminary calculations. Applying these values of L/D and T/F to equations (1) it is found that $\sin\theta = \cos\theta$, whence $\theta = 45^0$; i.e., the airship will sail within 45^0 of the apparent wind.

Speed, and Inclination of Course to True Wind.

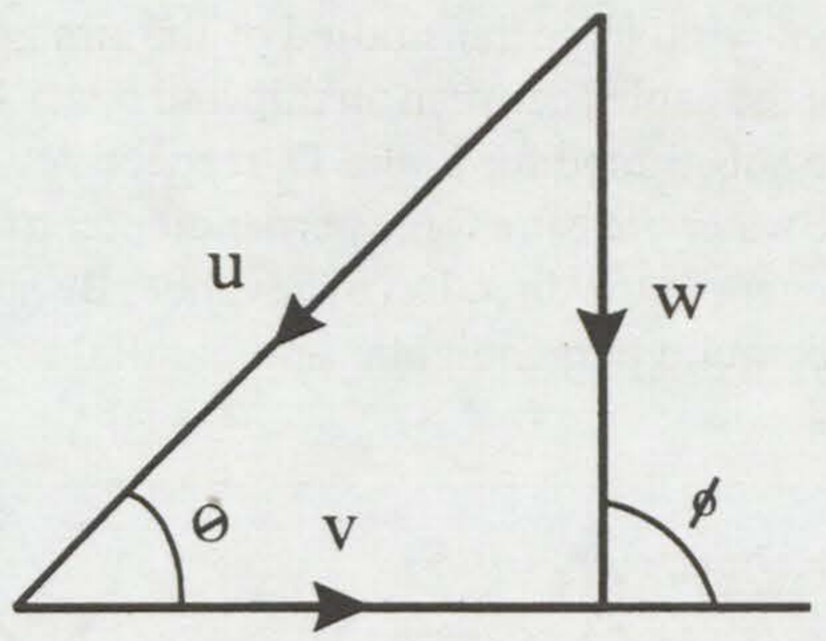


Fig. 3

In the diagram, Figure 3, let:

w = true wind velocity
u = apparent wind velocity
v = ship's speed over water
ϕ = inclination of course to true wind.
θ = inclination of course to apparent wind.

$$u = w\sin\phi / \sin\theta, \quad ....(2)$$
$$v = u\cos\theta - w\cos\phi$$
$$= w(\sin\phi / \tan\theta - \cos\phi) \quad ....(3)$$

Given $\theta = 45^0$ as calculated on the basis of L/D = 2 and T/F = 3,

$u = 1.41\ w\sin\phi$
$v = w(\sin\phi - \cos\phi)$

When $\phi \pm 90^0$, v = w, ie the airship can sail across the true wind at the velocity of the wind. The maximum value of v is 1.41w at $\phi = 135^0$.

Let y = speed made good to windward when beating, neglecting the time lost in tacking,

$y = v \cos\phi$ .... (4)

from (3) and (4):

$y/w = \sin\phi\cos\phi/\tan\theta - \cos^2\phi$ ....(5)

Again assuming that $\theta = 45^0$,

$y/w = \sin\phi\cos\phi - \cos^2\phi$

$d(y/w)/d\phi = \cos^2\phi - \sin^2\phi + 2\sin\phi\cos\phi = 0$, when $\phi = 67.5^0$

Whence the best speed to windward can be made at $\phi = 67.5^0$. At that angle to the true wind, $y/w = 0.21$. From this it is evident that not much speed can be made to windward, but it is quite an accomplishment for an airship to make any progress at all to windward without expenditure of fuel.

Steering and Cable Arrangement

The angle of attack of the airship to the apparent wind should always be near that which gives maximum L/D, regardless of the relation between the course and the true wind. Wind tunnel data show that L/D does not vary much between 9^0 and 15^0 angle of attack. The desired angle can be maintained by attaching two cables from the boat to a single point on the airship at about a quarter of the length from the bow, and controlling the rudders in accordance with an angle of yaw indicator.

Cables to the two ends of the boat make it directionally stable. There is a kind of reversed control between airship and boat; e.g., to make the boat bear off, the airship must be turned into the wind so that it drops behind relative to the boat, thus slackening the after line and pulling the bow of the boat to leeward.

The forward cable must be a little shorter than the after one so that the airship will lie at the correct angle forward of abeam of the boat to give the most efficient ratio between the forces acting upon the boat ahead and to leeward. The best cable adjustment must be determined by experiment.

To reverse the direction of motion of the boat when tacking, the length of the two towing cables must be interchanged as the airship swings into the wind and off on the new tack.

Required Area of Hydrovane.

Both airship and hydrovane are most efficient at a lift coefficient of about 0.2 based on $(vol)^{2/3}$ for the airship, and on area for the hydrovane. The air and water speeds are also of the same order. Therefore the area of the hydrovane should be to the $(vol)^{2/3}$ of the ship in approximately the ratio of the densities of air and water. This is about 1/900.

Given an airship of 400,000 ft^3 volume, $(vol)^{2/3} = 5{,}400\ ft^2$, and the required area of the hydrovane is $5{,}400/900 = 6\ ft^2$.

In a 30 knot wind, the cable tension would be from 3,500 to 4,000 lb.

Tentatively, it is estimated that a boat about 16 foot in length would be satisfactory. Its weight empty might be 200 lbs. In strong winds it might be ballasted with water up to about 1,000 lb. gross weight to prevent jumping out of the water.

Didier Costes' balloon for hapa traction.

(US IV will contain a report on Didier's 'Zeppy II' project.)

Wind-Powered Commercial Submarines

by Theo Schmidt

Abstract

Several possible sailing systems are shown incorporating a submarine device connected by a cable to an airborne device. This will usually be a helium-supported kite or electric wind generator, or a combination of the two, and will be flown at such a height as to encounter the most favourable winds.

Introduction

The disadvantages of operating vessels on the surface of the sea are well known. To escape the effects of sea and swell and to avoid excessive energy loss through the vessel's own induced surface waves, its bulk could be put either below or above the surface.

Both submarines and airships have proved to be fast and efficient, but costly. The submarine has a good potential as a cargo carrier in large sizes if the cost can be reduced. Because much of this cost is related to engines and the need for experienced crew, the introduction of wind power along with computer control devices offers interesting possibilities. The purpose of this article is to look at some of the ways submarines might be so operated.

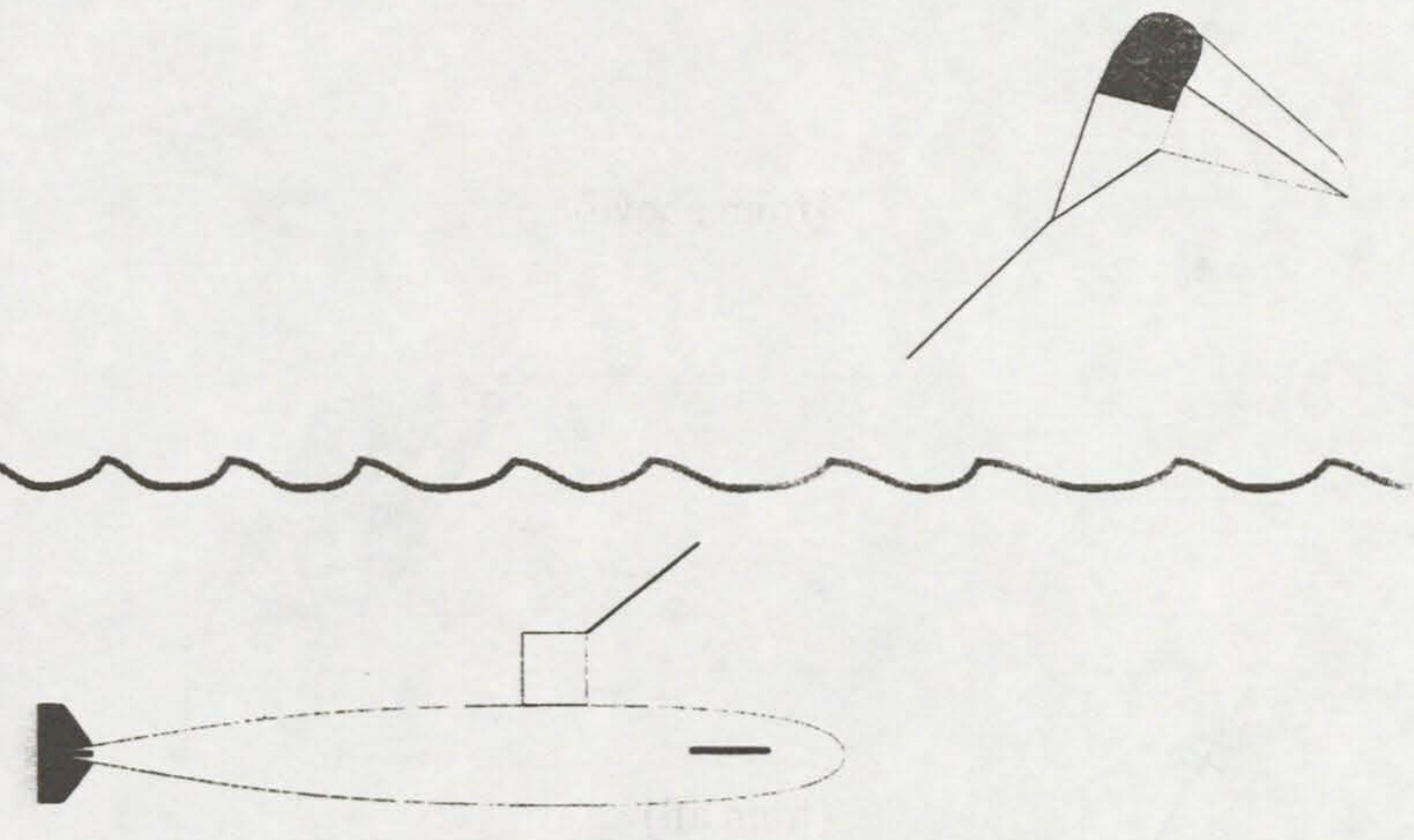


Figure 1. General concept.

Since conventional sails would not work on a submarine, the solution is likely to lie in the uses of devices flying high in the air and connected to the submarine by a cable. This would almost remove the effect of the water-air interface and would also have the advantage of using stronger and smoother winds than those available near the surface.

Kite-Towed Submarines

This concept spans a large range of possibilities. On one end we have the simple downwind towing of an ordinary submarine by a standard unmanoeuvrable kite.

On the other end we have a future system consisting of a submarine equipped with large fully-controllable hydrofoils and an efficient remote-controlled kite connected by a faired cable. Such a system could go to windward easily, and in stronger winds than conventional sailing craft.

Broad reaching courses are easily achieved if at least one of the components is very efficient or both are moderately efficient.

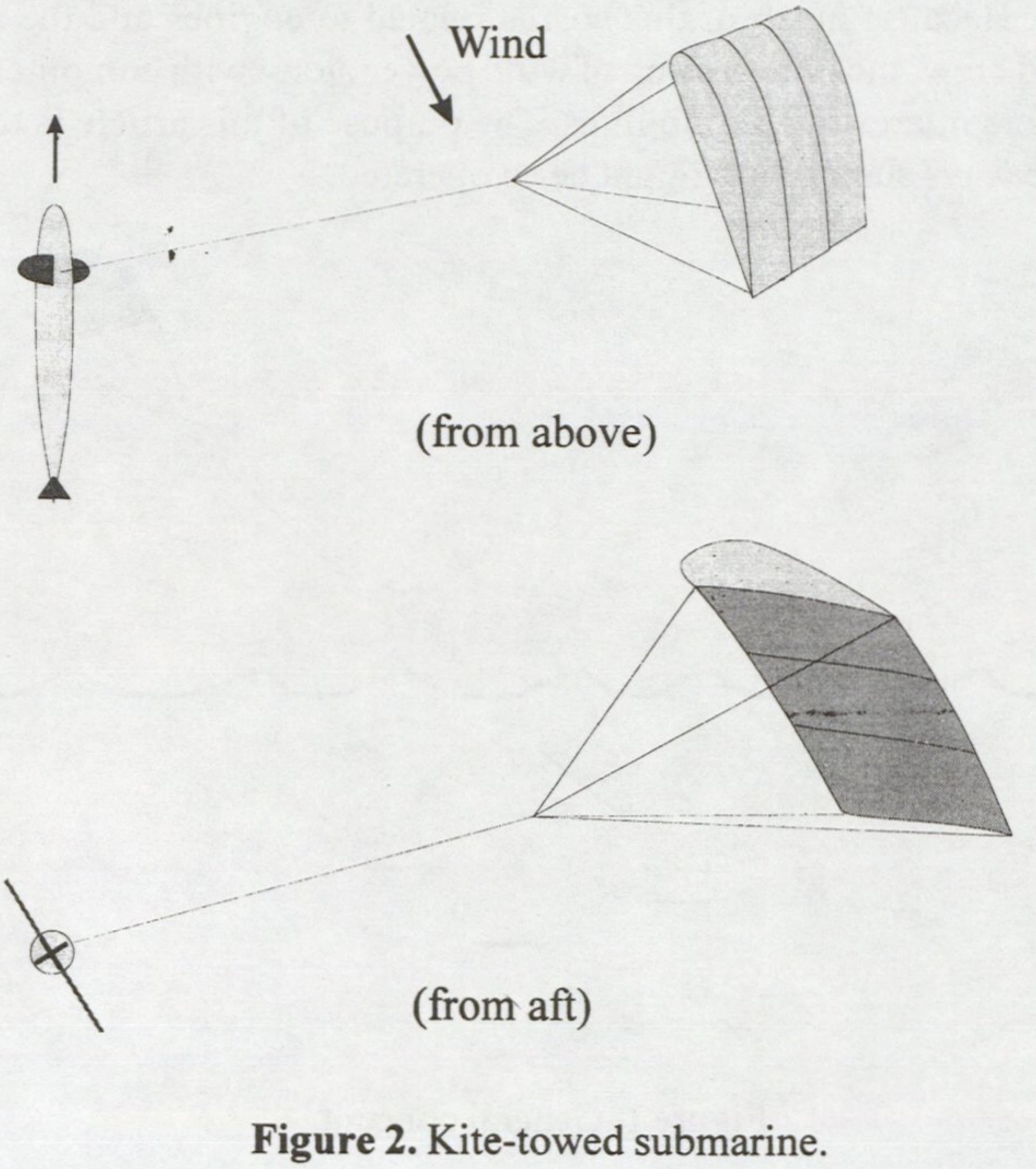


Figure 2. Kite-towed submarine.

The Components

The Kite

Many designs of kite with varying degrees of efficiency are available today, but only the uncontrollable single-line kites could easily be scaled up for direct downwind traction.

The kite must be able to achieve a reasonable lift to drag ratio *while pulling to the side*. In this situation it is difficult to use gravity as the stabilising force, as is usual in kite design. Therefore this must be replaced by another stabilising factor, such as electric or pneumatic control using a sonar or barometric device as height sensor. This complexity is evidently needed but is not yet available and is the obstacle on which research in this context must be concentrated.

Highly efficient kites are extremely unstable and will come down immediately if rigorous control is not exercised. Control is usually by twin lines, but in large sizes it would be better to steer the kite with flaps and rudders in a similar manner to an airplane.

Any kite for use at sea should be launchable from the water and therefore be of inflatable design, or at least have several air pockets incorporated. If it can be filled with hydrogen or helium to achieve positive buoyancy, light-wind performance will be much improved and the kite can stay in the air permanently, as long as it can be feathered or reefed by remote control.

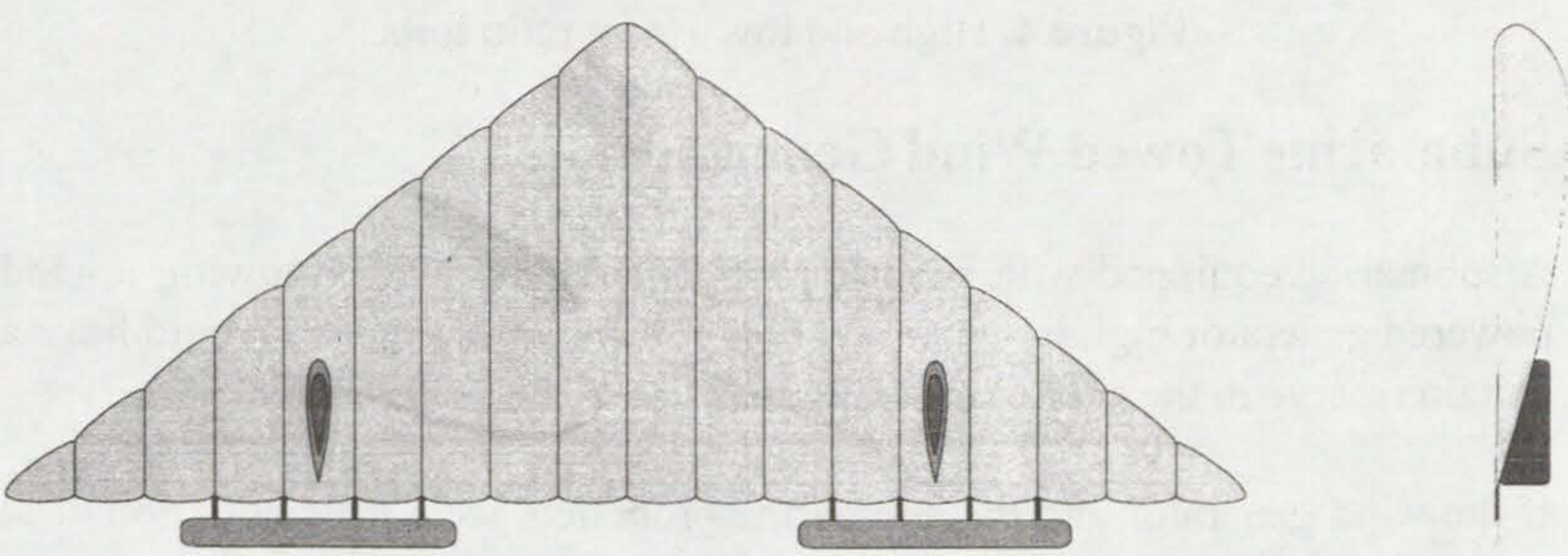


Figure 3. Inflatable kite/wing.

The Cable

The tension member would preferably be Kevlar, as weight and windage of the cable will impose a limit on the altitude attainable by the kite.

A fairing would be necessary at least on the underwater part and would also serve to enclose any electric power and control wires.

If a reeling system on the submarine cannot be avoided, this will also be a severe design problem, because it will have to be faired as well.

The Submarine

A present day hull design with added-on low aspect ratio hydrofoils would already be acceptable for all but the most extreme windward work. For this, larger and higher aspect ratio hydrofoils would be needed and it would be better to separate these structurally from the hull and have the large forces pass directly into the cable.

Control relative to depth should pose no problem and would be augmented by buoyancy control, as customary.

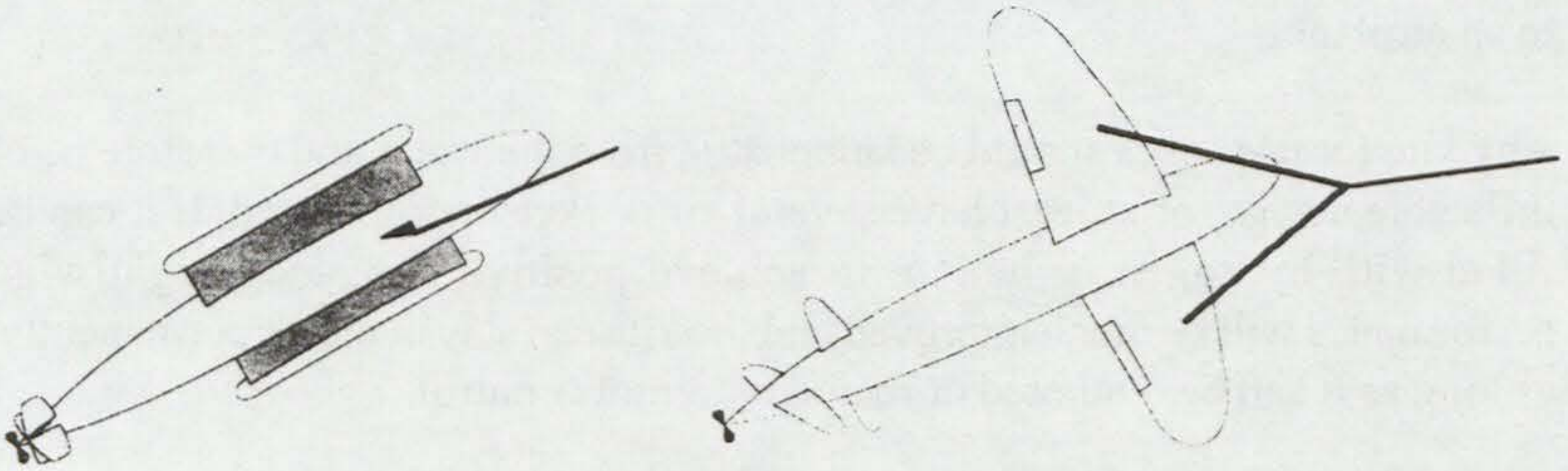


Figure 4. High and low aspect ratio foils.

Submarine Towed Wind Generator

A submarine equipped with electric propulsion, batteries and towing a wind powered generator high in the air, could go in any direction and would have a certain reserve in the case of no wind.

If the wind generator and the submarine propellers were efficient enough, it could even go directly against the wind without drawing on the batteries.

Going downwind, there is the interesting possibility of the submarine moving faster than the true wind by using the propellers and motors for generating power and the wind generator as a motor for propulsion.

Nothing much need be said about the submarine and cable at this stage, but airborne windmills are a fairly new idea and have not been built yet, except as small models, as far as the author is aware.

The Wind Generator

Having imposed the condition of having lighter-than-air support, most high-speed windmill designs could be used and the main problem would be to make them as light as possible without sacrificing airworthiness.

The kite and wind generator approach could also be combined to offer a degree of redundancy for safety reasons.

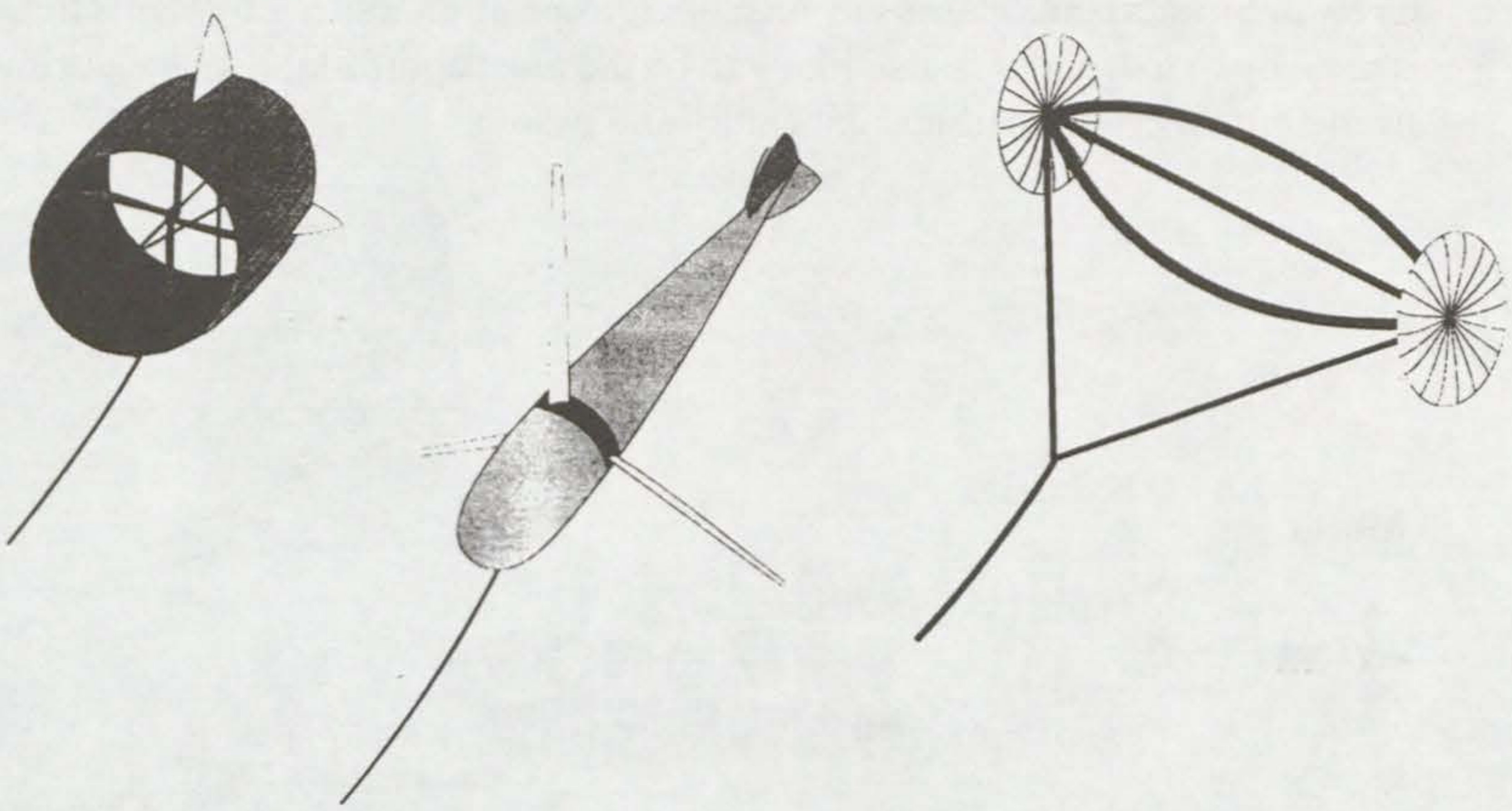


Figure 5. Generator options.

Catamaran Submarines

If two submarines were to be connected together rigidly, outside moments could be compensated by buoyancy control and windmills or wingsails be directly mounted over the hulls. This approach is not as attractive as the preceding proposals but has the advantage of being more conventional and perhaps easier to design.

Crew and Cargo

The best place for cargo of normal density is of course in the submarine. If it will stand ambient sea pressure or can be packed into pressure-tight containers, the hull can be much lighter than is usual in large submarines, provided buoyancy forces are properly distributed. Separate spherical pressure-tight containers would provide space for people or delicate equipment.

The hull would simply be a fairing for the cargo containers and other modules and would be subject to no major forces other than hydrodynamic drag and wave forces when surfaced.

There are many ways to position the crew in such a system;
Crew in Submarine. This is the most obvious position, especially if machinery is to be operated, and it is also likely to be the most comfortable place during a storm, but otherwise perhaps unhealthy and boring.

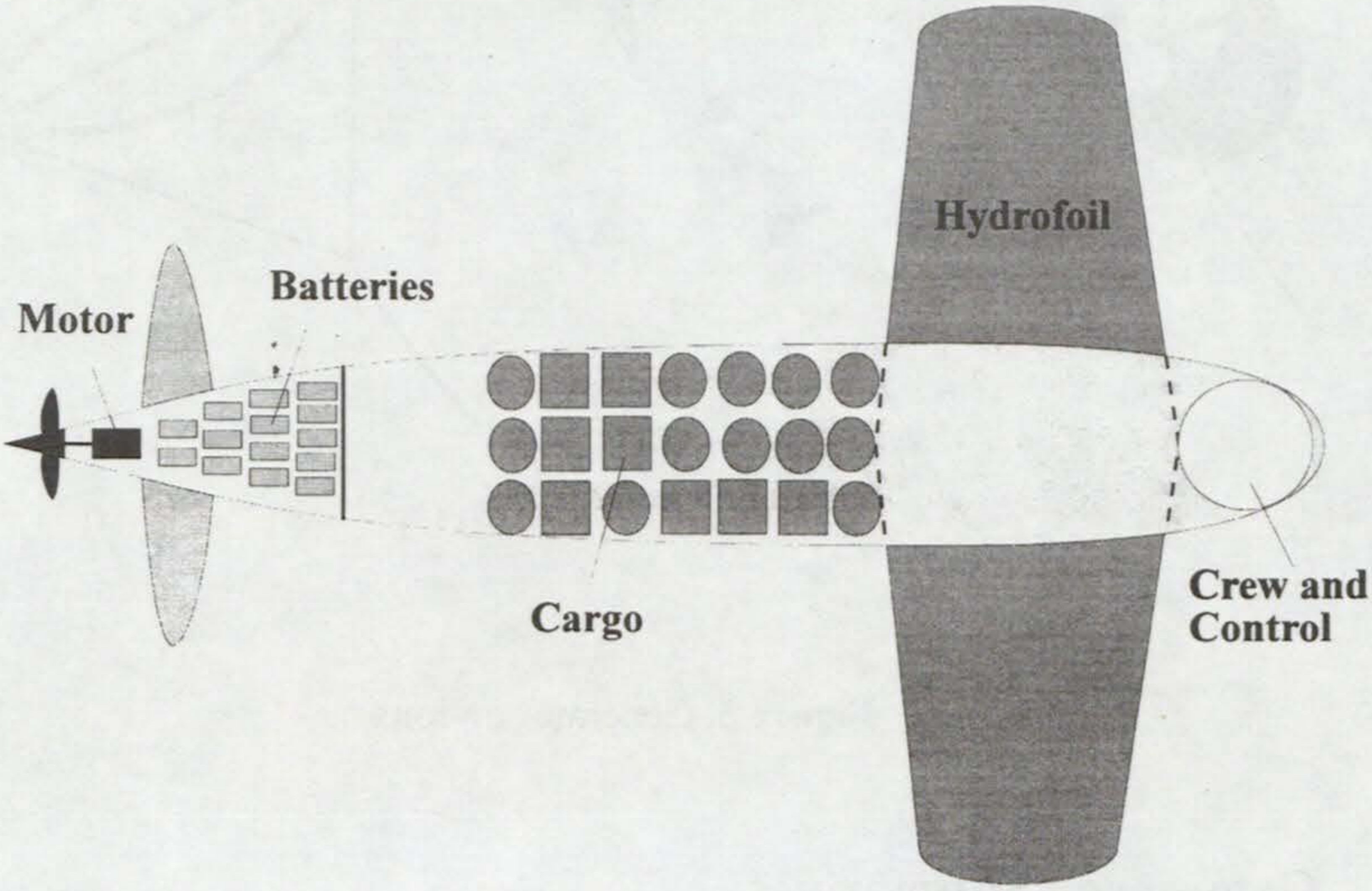


Figure 6. Accommodation plan.

Crew in Surface Vessel. A small boat towed from the connecting cable would offer the greatest safety in case of failure of the whole system, at the cost of a small increase in drag. The boat would contain control and navigation equipment and would be capable of servicing and launching the kite/generator.

Crew in Nacelle Suspended from Kite. This would be possible in very large systems and would put the crew out of reach of the waves as well as offering a good lookout position.

Crew in Kite This would be an advantage if the kite were built along the lines of an airship. For passenger transportation the submarine could be reduced to the bare hydrofoil and the resulting sailing Zeppelin would certainly be an exciting way to travel, although a free Zeppelin is much faster at the cost of relatively little fuel.

Completely Unmanned This is a future possibility if the reliability of the devices is high and they can be controlled and navigated by computer and remote control. Occasional repairs could be carried out by fast patrol boats.

Coastal Operation

The proposed systems could not operate safely near land and there would have to be a method for either taking down the kite/generator or mooring it at sea. The submarine could then approach land on the surface under auxiliary power or under tow.

Model Experiments

Experiments by the author and members of AYRS have been partially successful. Downwind runs are easy to do. Reaching courses are also not difficult to achieve, but there is a tendency for fast systems to behave erratically. Stability is achieved at the cost of speed.

Conclusion

If some of these ideas can be made to work they will undoubtedly prove to be one of the fastest and most efficient forms of sailing, although not a very practical one.

A great deal of work is needed for any but the most basic kite systems and there is no traditional experience to draw upon, so it is likely to be a long and difficult process. It is all the more important to begin researching such projects early.

Hapa Development 1980-1985

Some notes by Theo Schmidt

Inspired by J.G. Hagedoorn, my first hapa was a replica of the one described in his booklet Ultimate Sailing (republished in AYRS 114), the one with a circular meniscus-shaped foil. Although it worked well first time, its efficiency was not all that good. Hagedoorn proposed the circular foil, even with a bearing connecting it to the strut, in order to prevent any moments upsetting the stability of the float. This however severely curtailed the performance possible and I soon made other models with higher aspect ratio foils which worked better.

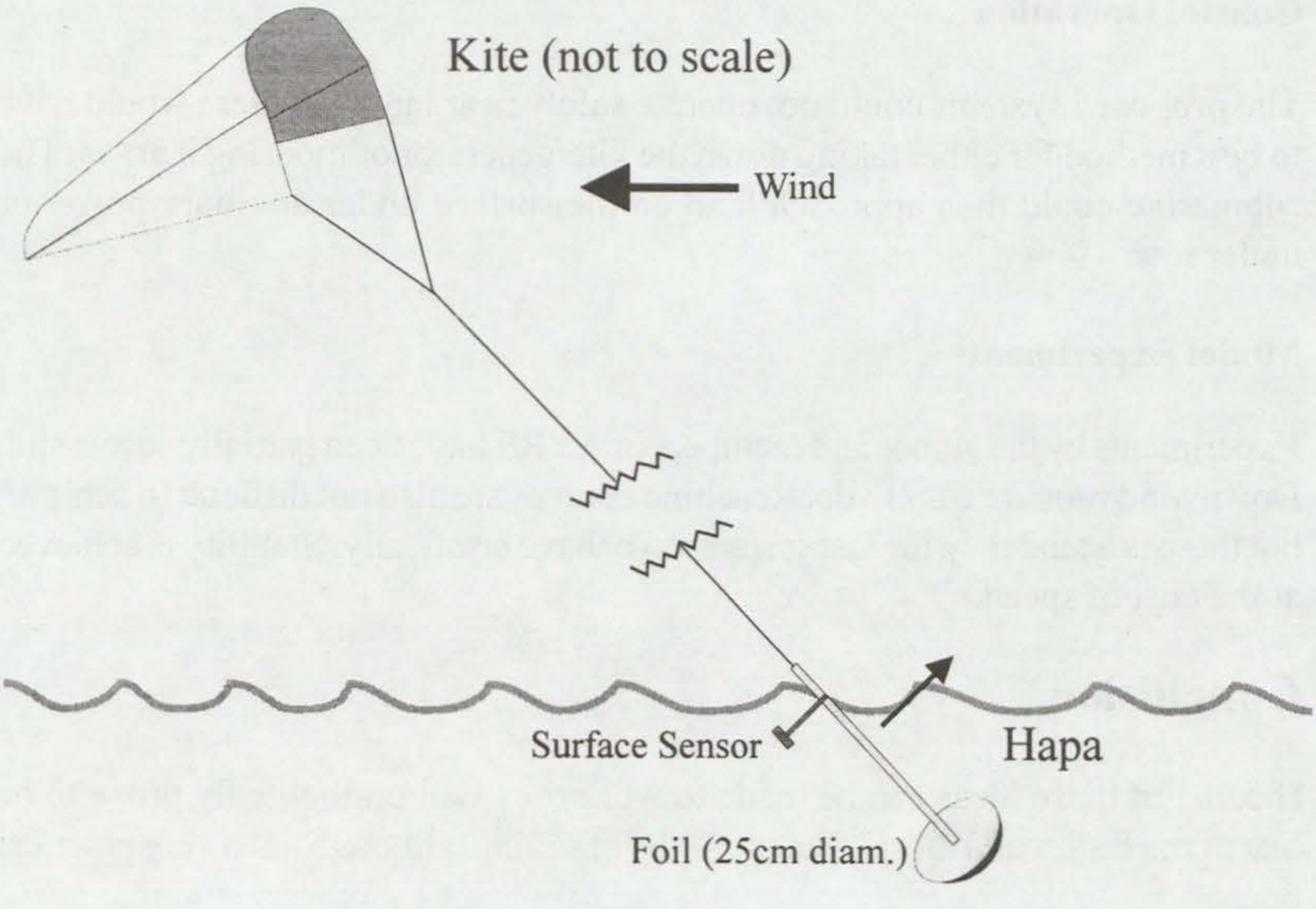


Figure 1. Kite and Hapa (with surface sensor)

As would be expected, a low-efficiency hapa is more stable: you just throw it in the water and, unless it is actually pointing the wrong way, it will begin to work properly on the first pull. More efficient hapas with longer, more slender foils are more difficult. They have to sit the right way in the water to begin with and are prone to stalling and/or ventilation if initially jerked too hard.

Hapa testing was done in the river Rhine at Basel and occasionally in a mill-stream, but from the very beginning I also tried them out with simple kites, constituting very basic hull-less sailing craft capable of broad reaching only, albeit intrinsically self-steered.

The problem of the hapa is the same as with its aeropleustic analogue, the kite. The attitude of both devices is controlled by gravity, eg by floats and spars in the one case and by tails or other weights in the other. The stabilising forces are thus constant whereas the hydrodynamic and aerodynamic forces increase with the square of the relative speed. Thus, when the wind blows too hard or the hapa is pulled too fast, the dynamic forces may overcome the stabilising forces at some point and a simple kite may tend to dive and the hapa to jump out of the water or to dive. These stability limits are easily reached with models while larger devices are more well-behaved in most circumstances. Ultimately, active stabilisation techniques would be necessary, such as a depth sensor activating a servo mechanism. I tried a submerged pressure-sensitive bellows acting on an elevator once, but it was difficult to see whether the device actually worked properly.

My hapa models grew in size, the largest having a rectangular foil about 1m x 0.25m. In the meantime, testing was being done in Portland Harbour as kiteman, Keith Stewart, had offered me a job for kite and hapa development at his firm Stewkie in Dorset. I developed a hoop-shaped hapa which worked reasonably well and we tried two versions of this with Stewart's large, helium-filled inflatable kites. These kite-hapas were very stable and could even self-steer to windward by tilting the kite to one side with weights.

The next step was to use radio control in order to sail the kite-hapa in any chosen direction. For this, the hapa was fitted with rudder and elevator, the idea being to gain control also of the depth of the hapa underwater, which was however never successfully attained. The kite was fitted with a weight-shift device which allowed it to sit stably at any point up to about 45^0 either side of downwind. As the hapas were more efficient, this allowed going to windward or indeed any direction by setting kite and hapa accordingly.

One problem was the amount of ground lost when working to windward and having to gybe (tacking a kite-hapa is probably impossible). This was countered by the use of a proa-type hapa which always has the same windward and leeward sides yet can change direction by shunting. We used a hapa made by Didier Costes (easily the most efficient hapa I had ever seen). Because this had an asymmetrical foil, it had a good tack and a bad tack. However, even when using the foil backwards, it was still pretty good. The static stability of the (hollow) hapa was increased by adding just the right amount lead shot. The direction was controlled by winching the line attachment point fore and aft with a small motor and screw drive.

These preliminary experiments proved the principle and were promising. A lot more work would be needed to make the devices reliable and practical, for instance for use as meteorological or oceanographical measuring instruments, or scaled up even as manned sailing craft as envisioned by Hagedoorn. The difficulty of experimenting with manned craft is the element of danger which is far greater than with more conventional craft. My dreams of skimming above the waves in a nacelle suspended from a kite-hapa proved elusive; the closest I got was water-skiing by kite on several occasions. This technique has since been developed much further by William and Cory Roeseler, who are indeed marketing kite-skiing equipment. Hagedoorn's dream of the aquaviator flying by parafoil with hapa still awaits some keen team prepared to develop the necessary technique and practise, practise, practise...

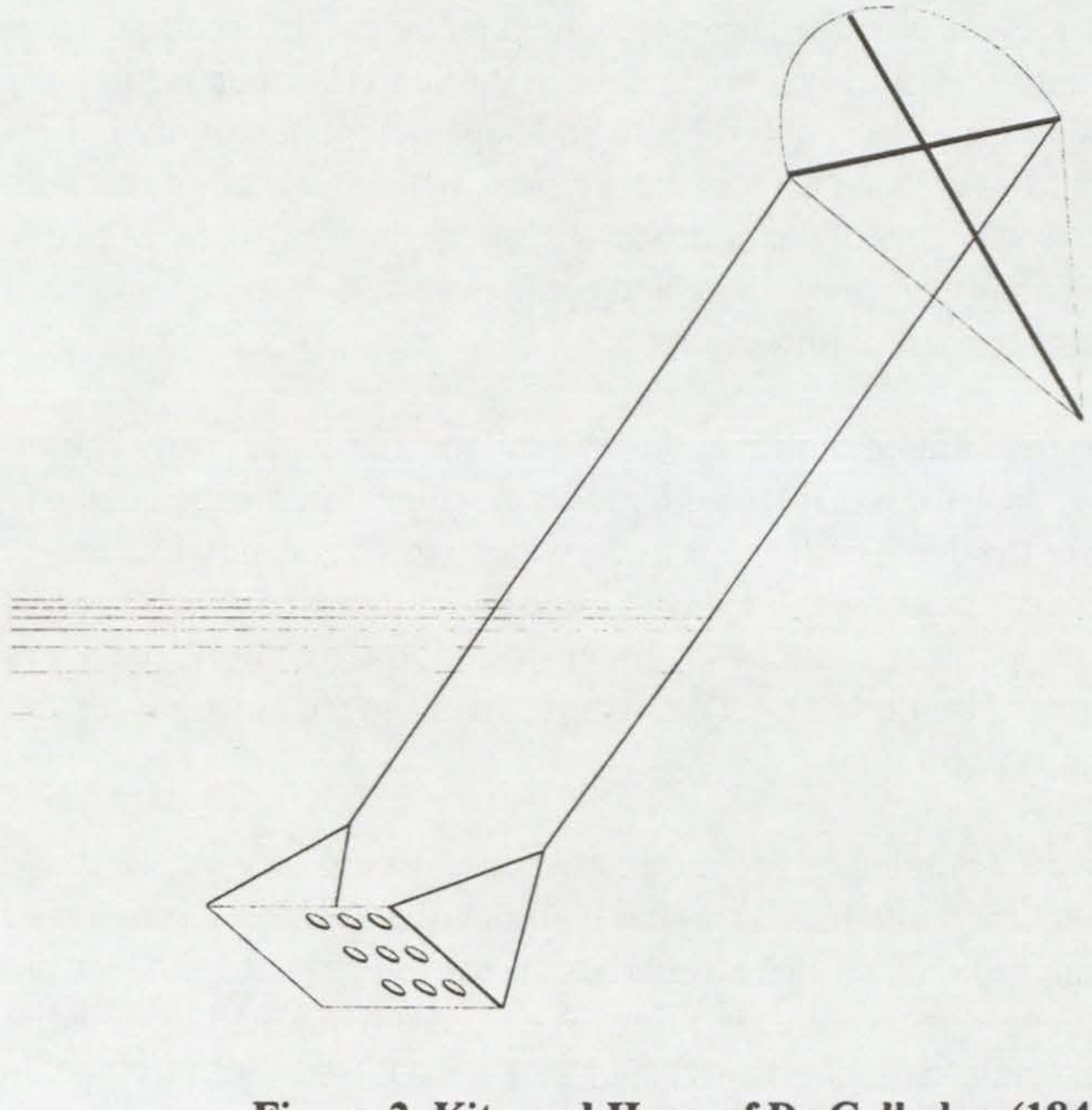


Figure 2. Kite and Hapa of Dr Collodon (1845)
See AYRS 108

Correspondence:

This correspondence followed on from Paul Ashford's report on his hapa trials in AYRS 114. The figures referred to by Paul were published in 114.

from Didier Costes to Paul Ashford,

I was most interested by the tests you reported in your draft. As Roger Glencross suggested, I present some comments:

1. Thank you for your references to my work and for using the name 'Seadog', which I use since the sixties.

2. I understand that you have in view a boat permanently stabilized by two sea dogs when at cruise, like a trimaran would be. Then the hull stability could be limited, maybe adequate only when no sail is used. Your challenge is then to show that no dangerous situation could happen, even during stops under sail and veerings. It was necessary, as you did, to make tests on mock-ups, since all combinations of adverse conditions cannot be fully analysed by theory. You certainly use the good methods for reaching this challenge, if reachable...

3. I consider that a completely stable behaviour of the seadogs cannot be guaranteed, for the reason that there will be a natural tendency for the skipper to sail faster and faster, in more and more choppy seas which may induce for instance sudden jumping phases of the seadog. I think that seadogs may constitute parts of special boats for speed, where capsizing is not such a problem, or be used as extra devices for cruising boats which remain safe by themselves and could forgive unexpected misfunctions.

4. If the boat is safe, I agree that it may be interesting to use two seadogs, to port and starboard, in order to tack or gybe in a continuous motion. At speed, the skipper will probably not keep in the water the lee one. If the same seadog allows good sailing in both directions, he may prefer to carry only one seadog and remove and reinstall it at each veering.

5. I prepared a symmetric seadog, to be steered in both directions, using only the two control lines. This allows gybing, with the seadog crossing the boat's wake. Such a seadog behaved well in mock-ups and was contemplated for the Atlantic Zeppy-2 airship, but in full scale towing experiments it gave insufficient stability

at speeds over about 10 knots and was temporarily abandoned.

6. The essential point seems to work conveniently in a large range of speed, keeping stability in waves and under unexpected high line tensions. The seadog shall hook again after a jump on a wave. For the airship, we found it necessary to use only one line, the incidence of the wing being automatically reduced when the force increased, in order to avoid breakage or jumps. The seadog could be towed in flat waters up to 25 knots before loss of stability, the traction reaching about 1500 N, but only to 20 knots in a very choppy sea, however with some jumps to several meters and huge shocks at the rehooking. With the airship, this seadog is reported to have jumped many times during a night sailing at a speed between 15 and 20 knots, rehooking very correctly without too rough efforts, thanks to the long line. It broke however finally, at the junction between the wing and the tail, which was not conveniently reinforced.

7. Another important point is to allow a good lift-to-drag ratio, and this requires a sufficient length-to-chord ratio. I used ratios over 5 in cantilever wings, without the dragging immersed stays. You seem to contemplate less performing features.

8. The pitch stability at speed seems more easily obtained using an immersed aft tail than a front surface feeler, prone to jump on a wave. The distance of the stabiliser to the wing is to be increased as much as possible; this length seems a bit short in your drawings.

9. The 'cat-dog' (splendid!) shape seems to correspond to your pair of seadogs solution, with long periods of low tension. For other ones, it is true that the lateral arm shall be sufficiently profiled not to hit the waves too roughly, and shall be floating. A difficulty is that this arm can occasionally dive with a negative incidence, in a stable faulty position. A supplementary end floater could be useful, with your front bridge against the risk of line winding around it. Against the risk of diving, the front end of the floater and the bridge shall be profiled with a positive incidence. I prepare another solution for avoiding arm diving in tacking seadogs.

10. In your Figures 8 to 10 you show a relatively short distance between the boat and the seadog. As the seadog may run parallel to the boat, but with relative longitudinal motions according to the remaining roll, my impression is that your seadog could be put occasionally in detensioned conditions and finally capsize or hit the boat. I would prefer a longer distance, which moreover makes the efficiency better, but this is easy to be optimized at the stage of tests.

11. You seem not to consider roll control and canting the sail to windward, a most interesting solution for non-keeled boats. In the sixties, I made successful mock-up experiments of a sailing single-hull boat with a seadog. A beautiful planing was obtained only when canting the sail like in still not known sailboards. Since this time, I had practically no opportunity to verify it at full scale, because I concentrated on proas with non-heeling sails, but my last unit could be used with a sailboard.

If you think that I could be of some help to you, please don't hesitate to contact me. For your information, I join the last Patent I took on the matter.

from Paul Ashford to Didier Costes

1. Thank you for your interesting comments on my draft article on seadogs. Clearly they can be used in many forms and ways. You are right in thinking that I am trying to develop their use as optional extras for a cruising boat which can sail without them.

2. My own boat is fairly light, and needs early reefing. With a length of 7m she has outsailed modern 10m cruisers in winds of Force 3, but this advantage is progressively lost as the wind strengthens. I sail in quite narrow rivers, where inland the winds tend to be light, and the use of seadogs would be inappropriate. I also sail in the North Sea, and it is there that I would like to use seadogs. Before considering it worthwhile to proceed at full size, I have been searching with models for a solution to meet two essentials. One is good behaviour in waves, the other is that the seadog must be convenient to carry on board for river sailing toward the sea or marina berthing.

3. This last requirement limits the foil length, and the area estimated necessary for sailing to windward, or when reaching to pass the 7 knot resistance hump to plane at perhaps 10 knots, dictates a fairly low aspect ratio (length to chord) of about 3. I appreciate that a higher ratio as used by yourself would be more efficient if practical.

4. This is a relatively low speed use for cruising, avoiding some of the problems of extreme build up of foil forces which you have described. The configuration is chosen for safety and allows shedding of gust wind forces by heeling.

5. Since writing my first draft my researches haved moved forward, and I enclose for your interest additional pages 9 to 13 and figures 11 to 18. I hope that I have

now found the answer to my needs in 'Anchor-dog'. Its behaviour in waves is much better than that of the other seadogs I have tested. This is because the forward foil is driven to follow the wave profile by foil forces rather than gravity, and this allows a very quick change in attitude when moving fast. The surface piercing forward and aft foils can be arranged to operate at a lower coefficient of lift than the submerged main foil, which minimises wake and problems of foil ventilation. This seadog has structural advantages with lower bending moments than an equivalent hook-type seadog.

6. I note that you have found an immersed aft foil better for pitch stability than a front surface feeler dropping under gravity, and my own experiments tend to confirm this, 'hook-dog', being less prone to jumping than 'cat-dog'. However, aft tail types still seem to suffer a problem because after running up the wave face the main foil arrives at the crest and emerges with positive incidence in the vertical plane; this must reduce the hooking down action needed if gravity is insufficient to drop it into the backslope of the wave.

7. It is interesting that both anchor-dog and your latest seadog reduce resistance by lifting the longitudinal float off the water.

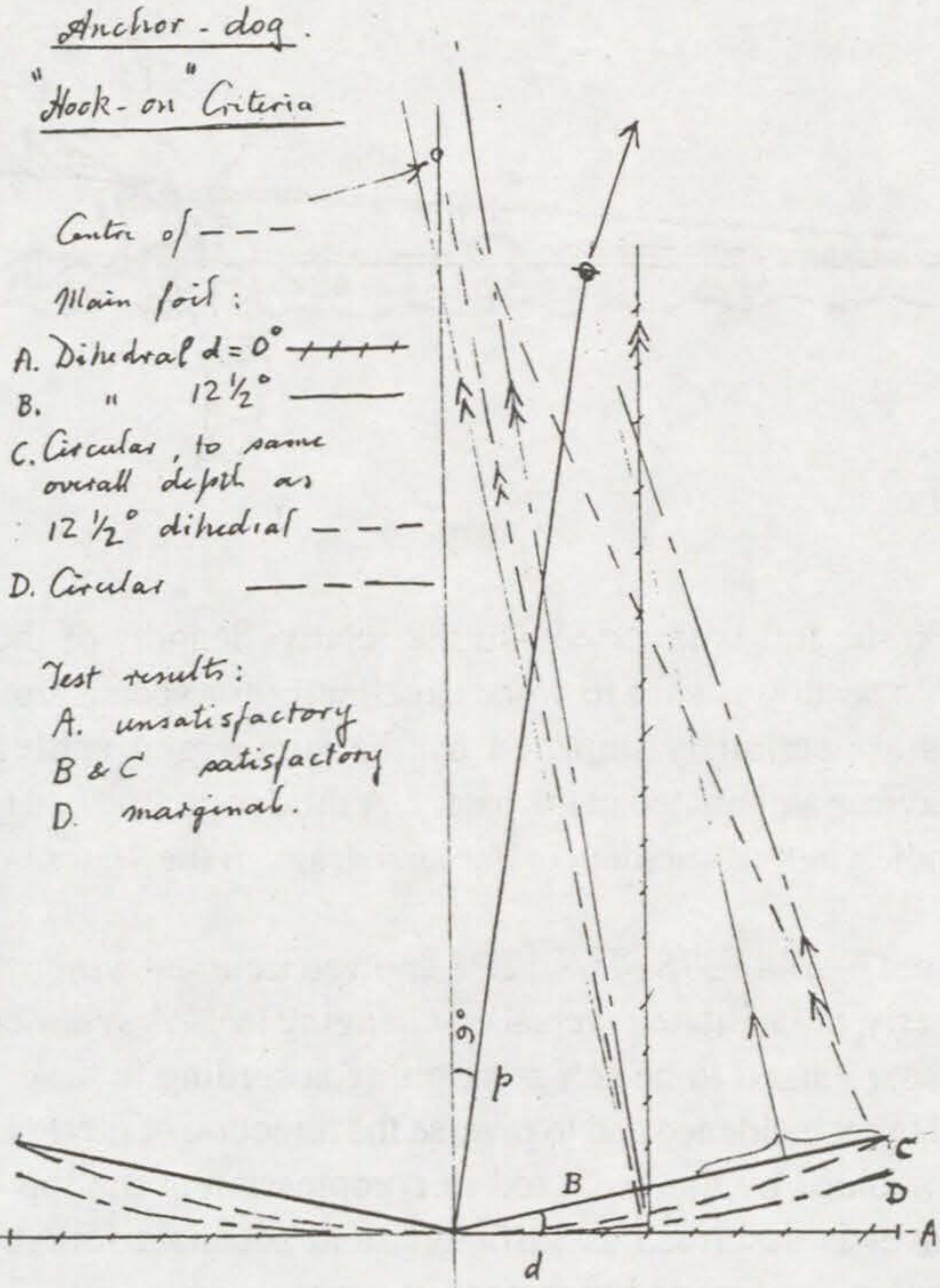
8. The idea of trying to use a single reversible seadog had attractions, but I decided to use a pair for the following reasons. Firstly recovering and launching with permanently rigged lines should be easier than transferring one seadog from side to side. Secondly there is the possibility of short tacking and gybing with both seadogs in the water, although best speed will be obtained with only one. Finally, sailing with both may prevent downwind rolling.

9. The use of a seadog to heel the boat towards the wind and obtain lift from the sail sounds an exciting possibility. I think that for a yacht with a practical cruising weight it is probably better to utilise some of the boat's stability by allowing limited heeling in the conventional direction. The first 10^0, for example, of heel mobilises a useful hydrostatic moment to carry sail, which is nearly free in terms of additional hull form drag, loss of sail efficiency and crew discomfort. To heel the boat towards the wind requires the seadog's line of force to act above the centre of the sails. I am wary of attaching a seadog high up the mast for sea-going use, where rolling may cause alternate slackening and snatching of the line; it does of course offer the attraction of obtaining a given increase in sail carrying power with a smaller seadog.

10. I am grateful for the views of someone who has worked extensively with

seadogs at full scale. So far my work has been confined to models, which will have to be scaled up by a factor of 4 or 5 for practical use. I hope this will not bring too many unpleasant surprises. I may work through a half scale model to complete design of chord sections, buoyancy and folding.

11. On page 10 of the enclosed addition to my report, under Model and Performance, there is some discusssion of the necessary dihedral angle, d. Since writing that, further tests have confirmed the dog will run with zero dihedral, but will then jump if stalled by releasing too much control line. It is necessary for the main foil wing nearest the yacht only to have a hooking geometry. The attached sketch summarises these tests. Foil B with 12.5^0 dihedral theoretically does not hook until more than 20% of the span is submerged, but hooks strongly at 50% submergence and has behaved well in practice. The asymmetry allows the line attachment to be nearer the foil than its axis of curvature, giving a compact seadog.



A Description of some Seadog inventions

by Didier Costes

Summarised from his recent French patent application

by Paul Ashford

The application begins with a review of the previous patents held by Didier Costes. No 1,494,784 of 18.05.1966 described a curved wing or foil symmetrical about the plane bisecting its span, and having leading and trailing edges. Extending aft is a spar carrying a small flat foil in the plane of symmetry, which stabilises it in pitch. It is towed by a bridle of two ropes attached to its extremities, which intersect beyond the axis of curvature. By making the top leg of the bridle shorter than the lower leg the foil is made to run with its upper end above water and say three quarters of its span and the tail submerged. Stability in yaw (and incidence) follows from the more or less forward positioning of the points of attachment.

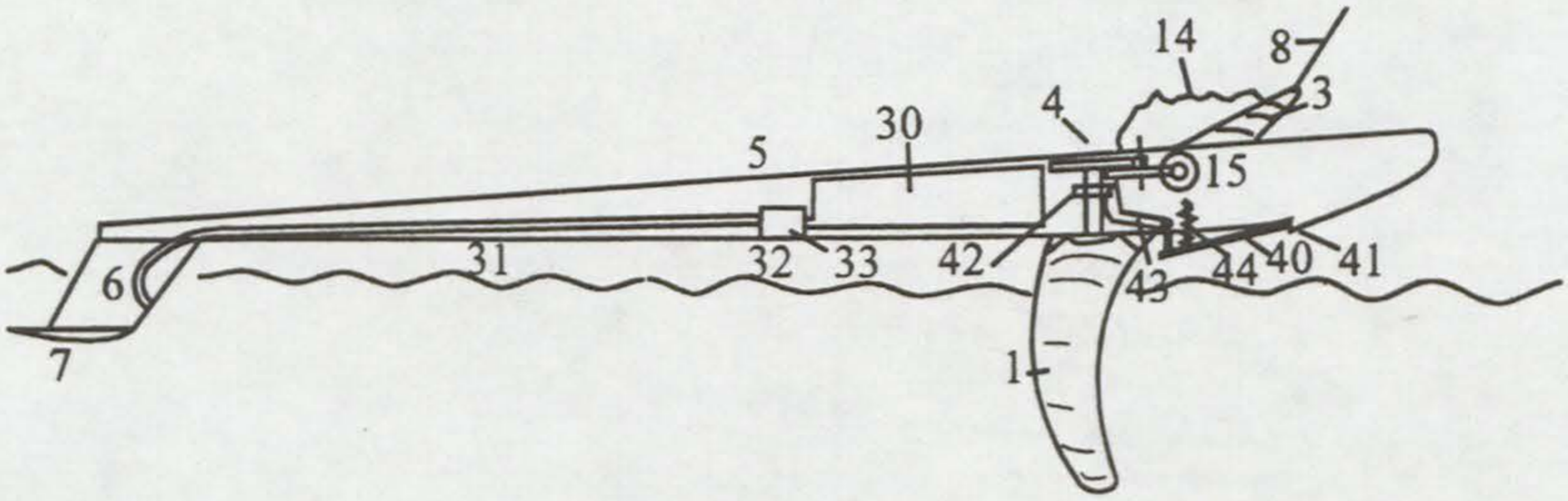


Figure 1.

To change tack, the foil is inverted and the relative lengths of the bridle legs reversed. Such a seadog is said to work excellently for speeds up to 15 knots. Higher speeds are seriously impeded by the submerged cable, in spite of streamlining devices anticipated in the patent. A third rope attached to the tail can be used to remotely adjust incidence, but also drags in the water.

His French patent No. 443 378 of 08.12.78 showed a curved wing with a vertical plane of symmetry, to facilitate reversal on changing tack. A symmetrical float is attached by a spar hinged to be self positioning according to tack. Two towing cables are used to set incidence and to reverse the direction of motion. Submerged cables can be avoided by the use a rod in compression at the top of the wing. Stability in waves is described as sufficient, and adequate foil strength could only be obtained at the cost of in increase in drag.

The present invention is aimed at better stability at high speed and in waves. The patent application gives a very detailed description, but the main features are apparent from Figures 1 to 4. The main elements are a curved wing or foil (1), similar to that described above, extended by an arm (3), carrying a vertical shaft (4), passing through the long float (5), carrying aft a rudder (6) and horizontal foil (7) for stability in pitch. The shaft allows the wing to be rotated to the port or starboard side of the float and can be equipped with various devices for adjusting or locking the rotation.

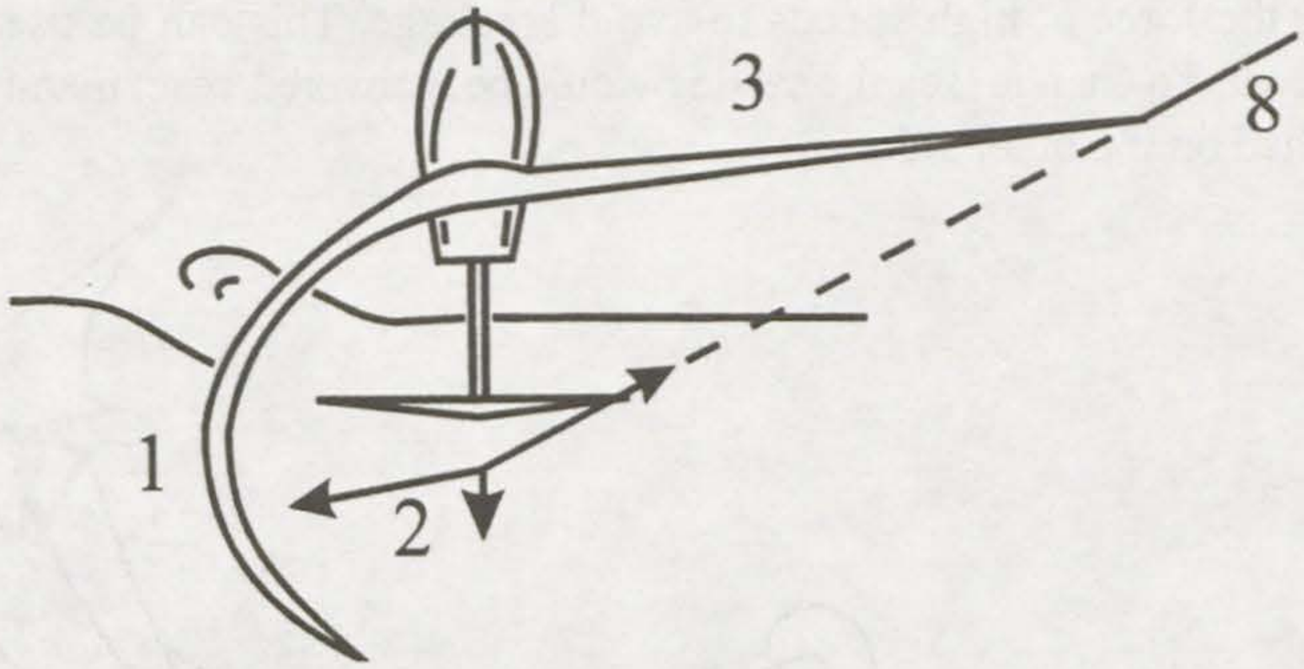


Figure 2.

The seadog may be used with a sailing boat, in which case it provides necessary leeway resistance in the same way as a centreboard, but being attached to the mast also resists the heeling moment. It can also be used in conjunction with a glider, kite, balloon or airship acting as a sail.

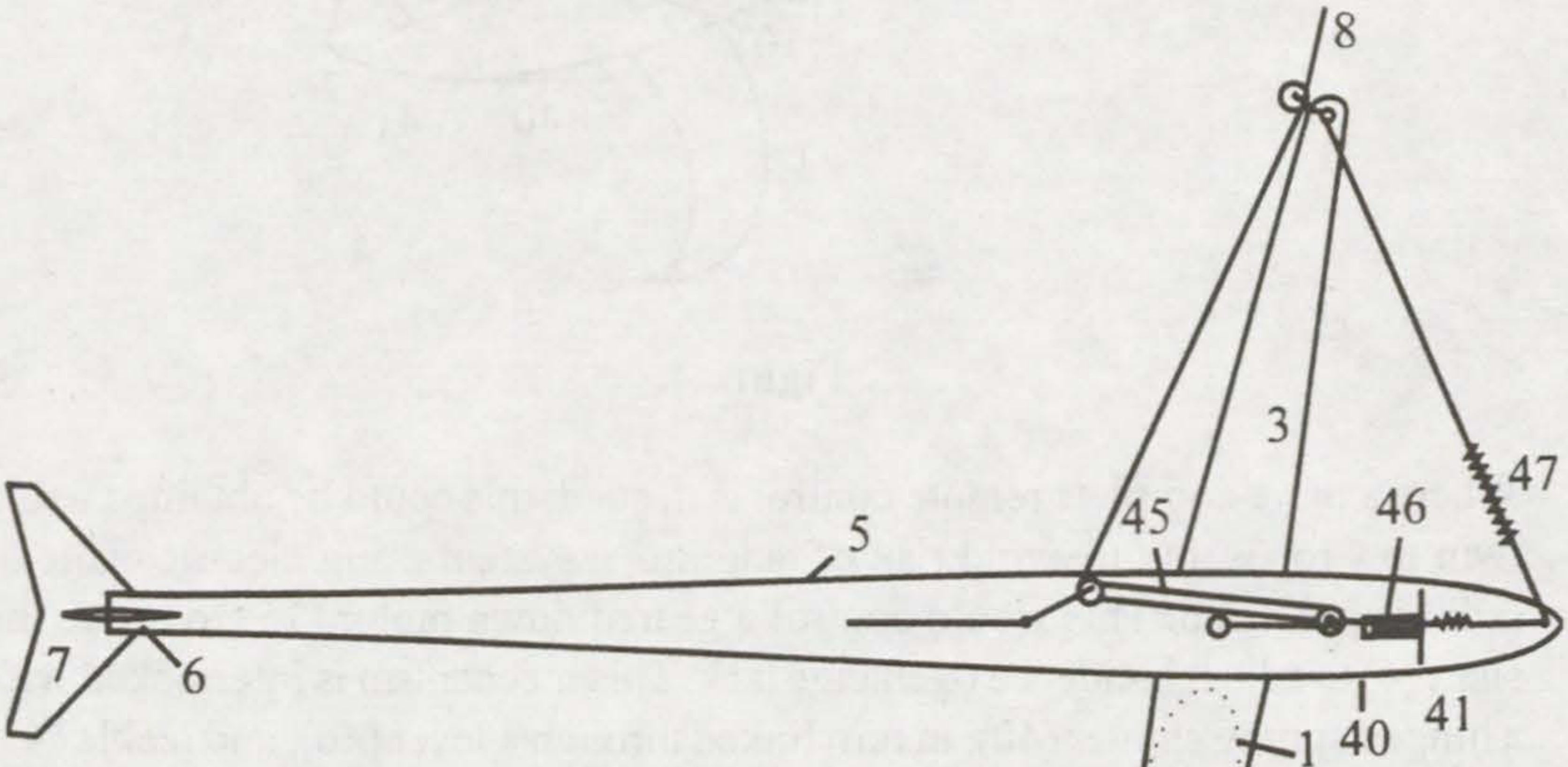


Figure 3.

Two basic types are envisaged: Type A (Figure 1) which does not carry a pilot, and Type B (Figure 4) with a seat for a pilot who operates the sail unit by remote control.

For Type A it is proposed to fix the tail and regulate the angle of attack, which controls the lateral force, by varying the angle between the wing and the float. The simplest system proposed, shown in Figure 3, uses a single tow line (8) and a spring (17) to automatically reduce the incidence as the tow force rises, thus limiting the force at high speeds to avoid breakage. This can be used with a sailing boat. To change tack the seadog would be recovered, reset manually, and relaunched on the other side.

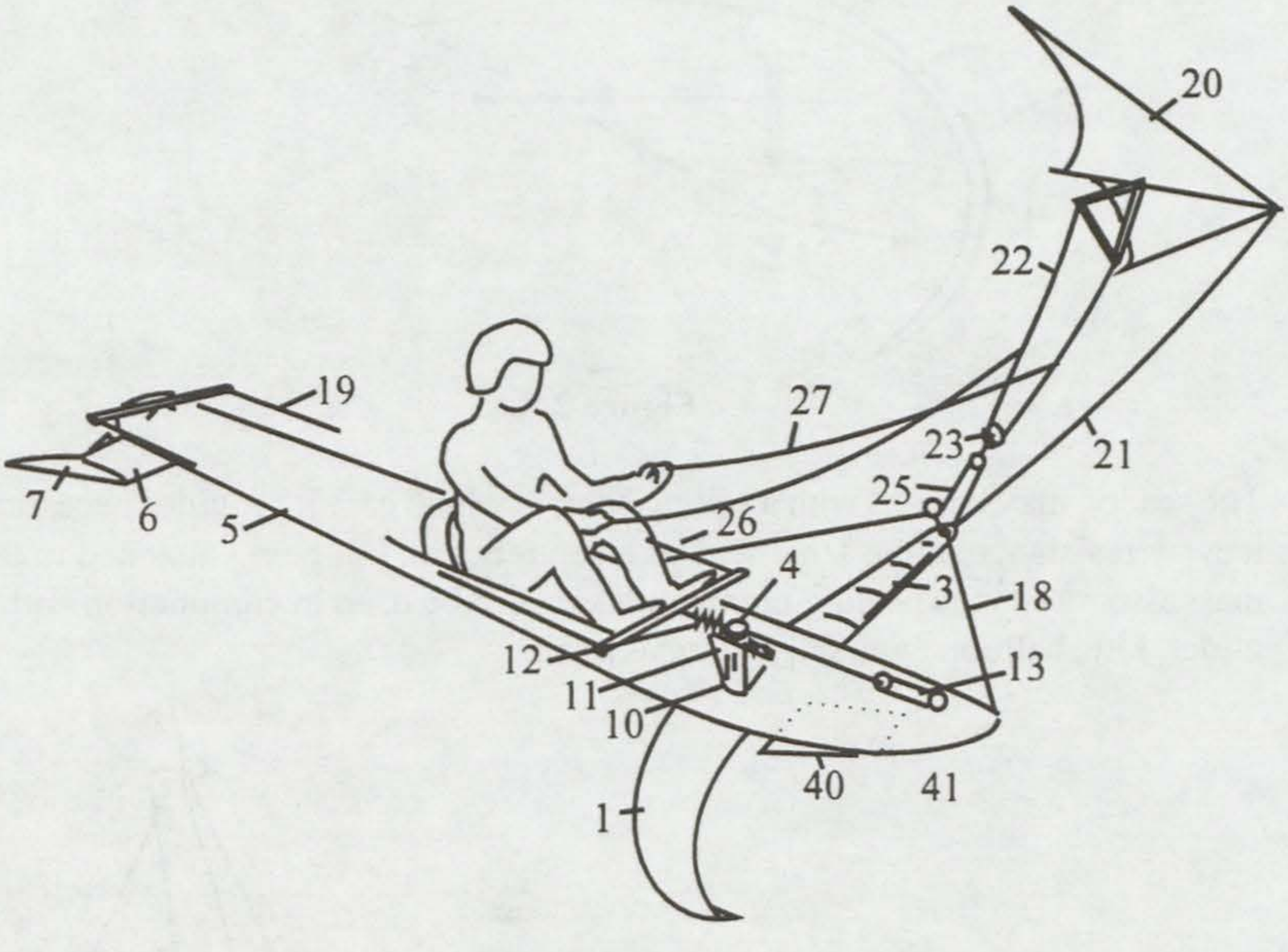


Figure 4.

Where a more complete remote control is needed, this could be obtained using twin tow ropes, but to avoid risk of tangling, a system using electric cable or radio is preferred. This would control a geared down motor (15) to rotate the shaft (4) to adjust incidence or change tack. This mechanism is interlocked with a hinged sprung shutter (40), in turn linked through a lever (46), and tackle (45) to the tow rope. Due to translation difficulties the action of this equipment is not fully understood, but it appears to be to protect the operating mechanism from high stresses due to waves.

For use with an airship or balloon (Figure 5), to counter a gain in lift due to solar heating, a system of water ballasting is proposed. A tank (30) can be filled by a scoop (6) in the foil or emptied through a vent (32) using a remotely controlled valve (33).

In Type B, provision is made for manually rotating the wing between tacks and locking its angle with the float. Incidence would then be regulated by use of the rudder (6), operated by a rudder bar.

To maintain normal wing immersion while supporting the weight of the pilot, either the wing is to be less curved or provision made to give it an overall angle of incidence in the vertical plane. To this purpose shaft (4) may be tilted in a slot in the float by a tackle (13) acting against a spring (12). Accidental release of the tackle would cause a rise, preferable to too much immersion, while the spring can absorb shock if the wing strikes an obstacle.

Figure 4 gives an example of remote control of a kite sail. Its angle of attack is controlled by a tackle (25) lead into a cleat (26). The reins (25) allow control of its roll and hence sideways positioning. An alternative is suggested of connecting the kite by a single rope, with radio control of suitable control surfaces on the kite or of mechanisms linking it to the tow rope.

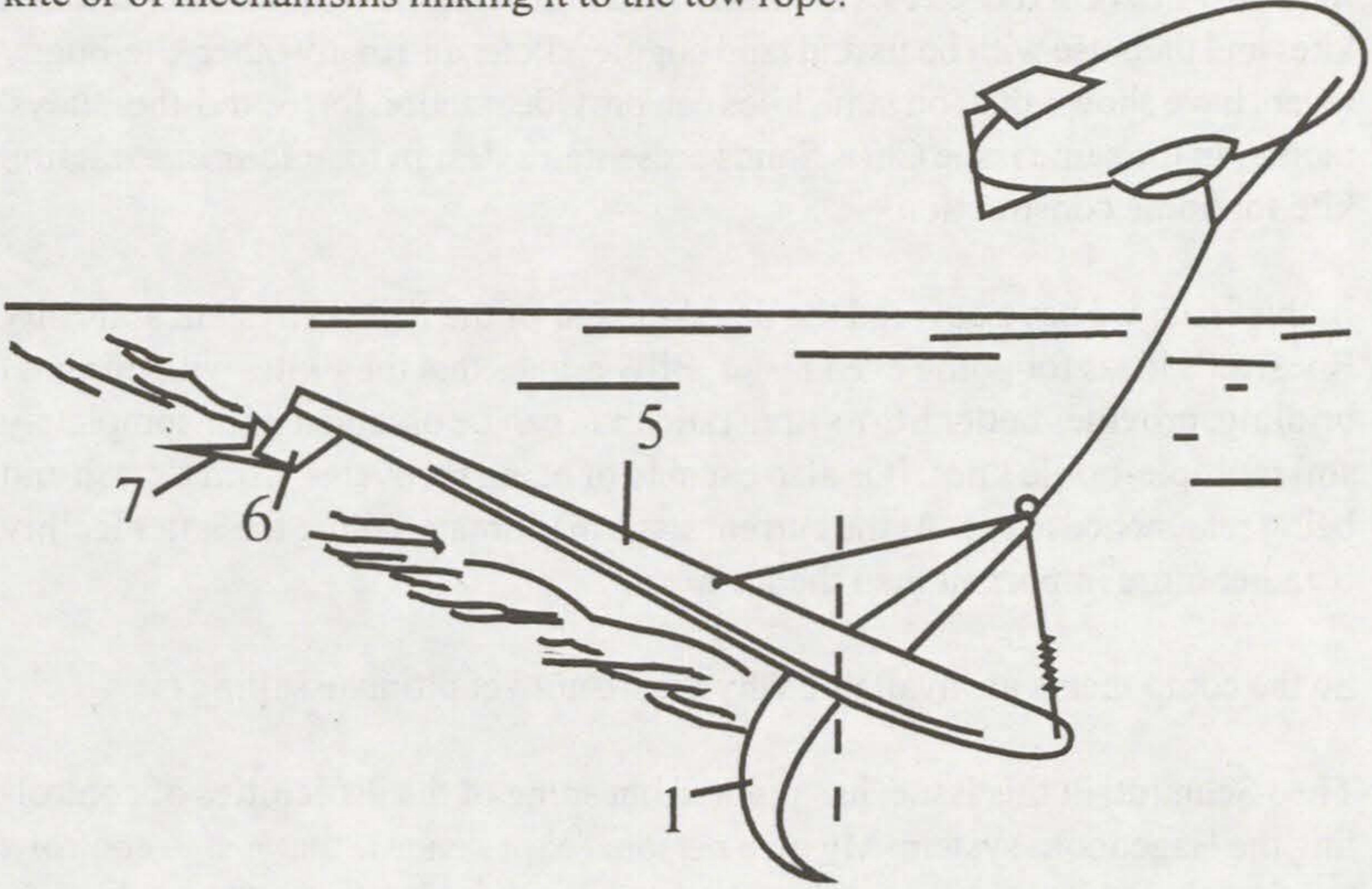


Figure 5.

Conclusion

We have now completed the first three of the AYRS publications in the ultimate sailing (US) series and we have covered quite a lot of ground, and water, and air..

It seems like a good time to take stock. AYRS 114 (US I) presented the basic concepts of the hapa/kite system first proposed by Prof Hagedoorn in 1971. The idea was that the two energy extraction devices of the yacht, the sail and the fin, could be utilised without the encumbrance of a hull. The sail (actually a kite) and the fin (a hapa or underwater kite) could be connected by a tether which they would hold in tension. The pilot would be suspended somewhere along the tether.

We then began to consider the individual elements in the proposed system. AYRS 114 also included the paper by Paul Ashford on his experiments with hapas, forming a practical guide for building your own hapa.

In AYRS 116 (US II) Peter Lynn described the development of his 'Peel' traction kites and their use with boats and land buggies. Peter and many other kite-buggy racers have shown that, on land, kites can provide traction for 'round-the-buoys' racing. In the same issue Chris Sands presented a design for a four line traction kite for home construction.

In this issue we have covered the development of the Kiteski system and Billy Roeseler's ideas for going even faster. Billy argues that their kite, with minimal bridling, provides better lift-to-drag ratio than can be obtained with completely soft multiple-bridle kites. It is also capable of being recovered from a crash and being relaunched at sea. At the current stage in ultimate sailing the latter facility is rather more important than the former.

So the components are available why are we not yet ultimate sailing?

Theo Schmidt, in this issue, has pointed out some of the difficulties of controlling the Hagedoorn system. My own personal experience is that just to control a traction kite while standing still on dry land can be a challenge. The problem is that to achieve the vertical lift required to support the pilot very much larger kites than are used for buggying must be controlled.

I have suggested in an earlier issue that kite-buggying could provide initial training for the aspiring ultimate sailor. Another possible answer is initially to limit the difficulties by using a lighter-than-air kite, the equivalent of the stabilisers on your first bicycle. Burgess has suggested the use of an airship, not for ultimate sailing but for the traction of a small craft. Theo Schmidt and Keith Stewart have experimented with inflatable wing-shaped kites.

There certainly seems to be merit in gaining the component skills one-at-a-time if it can be arranged. Peter Lynn flew large, powerful kites before he tried buggying and advises us to do the same. Cory Roeseler was a junior champion waterskier before he tried to kiteski.

My own belief is that the first person to experience the complete Hagedoorn 'ultimate sailing' will be a windsurfer, and that it will be almost by accident or from sheer exuberance. I am willing to take a small bet that he will probably not have heard of Prof Hagedoorn.

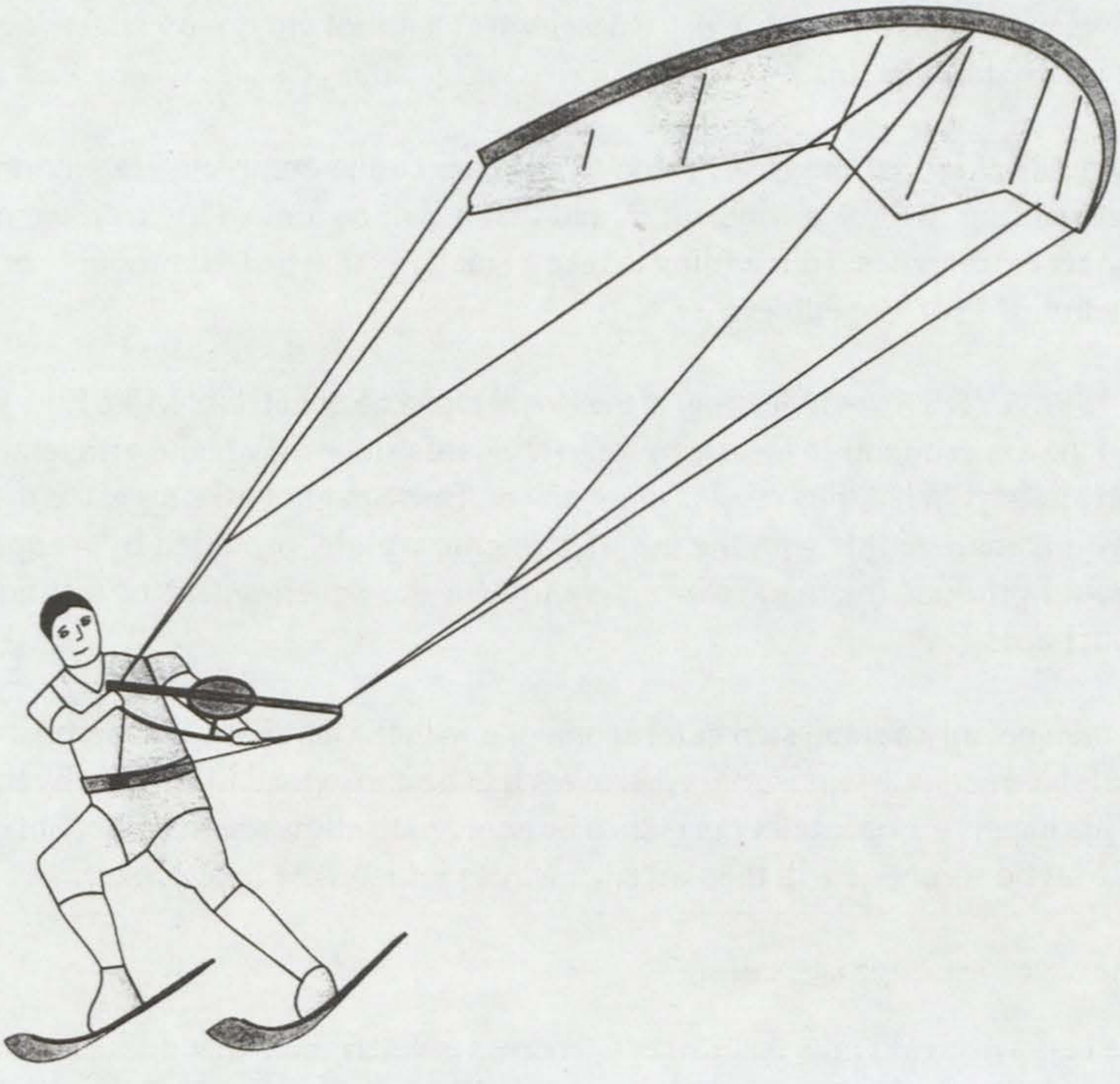
At the 1994 AYRS Speed Meeting, in the Royal Dorset Yacht Club, Mike Ellison decried the experiments in the use of foils for boards since they plane efficiently enough already. What they need is more power. Bob Spagnoletti suggested that they would achieve this with the use of 'dynamic weight' provided by a hapa. This could produce the market incentive to spur the development of fast and efficient hapas.

It will then be only a small step before someone with the acrobatic and aerobatic skills of the free-style windsurfers discovers that he can extend his flights by the use of his hapa. A longer tether may then be adopted to allow greater freedom of flight. Maybe someone will then invent a way to jettison the board itself.

Hey, now you are 'ultimate sailing'!

Maybe I am wrong. I know that Roger Glencross is determined that this is not the way that it will happen. There will be a report of Roger's progress in the next US. There will also be a report on Didier Costes' attempted Atlantic crossing with the hapa-powered airship, Zeppy II, some thoughts on kite traction from Dave Culp, and ideas from Bill Sherts for generating greater power from smaller kites by the use of dynamic sheeting.

The plan is that US IV will be the last of the series, or the ultimate 'Ultimate Sailing'. Ian Hannay, with his penchant for a catchy title, has suggested that the current issue should have been called 'Penultimate Sailing'.



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