10. Responses to challenges that have stopped others

Challenge	Response
10.1 "Some kite surfers find it hard to go upwind"	
i) While kite surfing the board is "edged" to provide resistance to lateral loads. The board acts like the keel of a sailing vessel to resist lateral loads. However the board geometry makes it much less efficient than the keel of a sailing vessel. The difficulty which some kite surfers have in making ground upwind results partly as a result of the inefficiency of the board for resisting lateral loads.	The *WINDFLY Rig* allows a keel to be used with the same efficiency at resisting lateral loads as the keel on a sailing boat.
ii) "A serious impediment to kitesailing is that the best traction kites available now attain an L/D (Lift to Drag ratio, the measure of upwind performance) of around eight,- but kites with this peak of performance currently tend also to be too twitchy and unstable for most conditions. Kites that are adequately reliable for general use currently have L/D's of 5 to 6. Conventional yacht sails can have L/D's in excess of 10. The effect of this is that kite powered sail boats are not very competitive upwind - sometimes taking more than twice as long as equivalent conventionally rigged craft on a given upwind course. For very high performance craft that are 'on the wind' even downwind, this deficit applies on all courses to some extent- though by using long lines and 'figure eighting' the kite while steering the boat straight downwind, it is usually possible for kite powered craft to prevail against everything else on reaches and runs- and often by more than a 2/1 margin on time. In the last decade or so, kite performance has been improving much more rapidly than sail performance has though, so there might not always be such an L/D deficit. Since 1980, useable traction kite L/D has improved by a lot, and there is a real possibility of dramatic improvement-hopefully to something approaching parity with conventional sails- within the next few years. Most promising hope are the aeroplane form kites currently being developed for kite energy projects, Rigid carbon fibre structures, they have huge depower, excellent control (by servo controlled surfaces) and should be able to achieve L/D's above 15. Notwithstanding their high weight/area ratio, because of their high L/D, they can fly in very light winds provided they are constantly figure-eighted." (http://peterlynnhimself.com/Kites_For_Yachts.php)	Accept the limitations of kite design at present … and be ready to take advantage of improved kite designs when they become available. If the WindFly Rig is mounted so that leeway is avoided, the closest course to the wind that can be achieved is approximately the same as for a conventional sail boat.
10.2 "Kite surfing only works in strong winds … you often cannot go kite surfing because the wind is too light" Kite surfing is generally only possible in winds of force 4 or greater. The reason for this is that the kite has to provide sufficient 'pull' to enable the board to plane (skim over the water surface).	Any boat using the *WINDFLY Rig* can travel in the displacement mode (passing through the water, like most sailing yachts), therefore it will be possible to operate even when the wind is not strong enough for the vessel to plane or lift up on hydrofoils.
10.3 "Kites don't even fly in very light winds" (ref. http://peterlynnhimself.com/Kites_For_Yachts.php) To be able to fly, a kite must have enough wind so that the kite generates sufficient lift to overcome the self weight of the kite. … "at less than 8km/hr wind speed, kites that are generally useful in traction applications will not stay up reliably".	Using the *WINDFLY Rig* a kite can be used to drive the boat even when there is insufficient wind to lift the kite off the surface of the water – a kite will pull even if it remains floating on the surface of the water … a very large kite can be launched to provide more drive than would be provided by the sails of a traditional yacht or dinghy. [Since most sea-going kites have an inflatable leading edge and ribs the kite will pull in the same manner as a sail even if the wind is extremely light.]

Challenge	Response
10.4 "The kite will fall from the sky during lulls in the wind, or if the boat overtakes the kite" *(ref.* http://peterlynnhimself.com/Kites_For_Yachts.php) At less than 8km/hr wind speed, kites that are generally useful in traction applications will not stay up reliably. Apart from when the wind is just not strong enough, there are various other occasions when such light wind is encountered: • One is when the kite is overflown and drifts back, stalled and windless until it is can re-engage. This may happen even when the true wind speed is quite a bit stronger than the 8km/hr minimum, but can be controlled by user friendly kite design and skilful flying. • Another is downwind sailing when the boat over-runs the kite. Never totally avoidable, careful coordinated control of boat and kite does help a lot though- and it's mainly a problem in light winds that are 'technical' rather than fun to sail in anyway. Downwind overflying is also more of a problem at the performance end of kitesailing; heavy slow boats using small kites don't have this problem. • The most annoying is when the wind is gusty (which is almost always for inshore locations) with periods when the actual wind speed is less than the required minimal. Up to 30 seconds or so of lull can usually be bridged, especially if the boat has good momentum and can be turned upwind a bit to keep the kite engaged with some apparent wind until the lull passes. Fortunately also, the highly developed kites used now for small boat kitesailing can generally be relaunched in the next puff even after they've fallen onto the water because of a lull- but on average, kitesailing is not currently possible unless the average wind is more than 8km/hr, and remains frustratingly difficult unless the wind is consistently more than 10km/hr. A distressing aspect of light wind kitesailing therefore is that conventional sailboats can drift along still making ground long after those sailing under kitepower are retrieving their dripping kite and lines from the water-or from the underwater appendages of some other boat.	Adopt user friendly kite design, hopefully also skilful flying, and skilful helming to turn the boat upwind to maintain airspeed during lulls. In addition a line tensioning system has been designed which may be incorporated into the *WINDFLY Rig*. The line tensioning system takes in the lines if the load falls, this maintains a minimum tension in the lines at all times. And finally - be sure to use kites which are water relaunchable!
10.5 "There is a limit on the maximum practical kite size" *(ref.* http://peterlynnhimself.com/Kites_For_Yachts.php) As kites are made larger, for structural reasons, they must necessarily become heavier in proportion to their size-which causes large kites to perform worse in light winds than smaller kites. A "magic" number is 200gms/sq.m of projected area. Kites that weigh much more than this generally handle poorly- and not just in light winds either. Aerodynamically literate non-kite-fliers find this almost impossible to believe- they 'do the numbers' and determine that kite weight is such an insignificant proportion of kite pull in even marginal winds that it can't be a factor. It is though. • Framed kites (of the delta style for example) are severely limited by this scaling effect (with current materials)- to about 15sq.m. • Hybrid style traction kites, like C Quad's for example, are less limited but would certainly become too unwieldy over about 30 sq.m. • LEI's (inflated leading edge single skin kiteboarding style kites) are less limited and can certainly be taken to 100sq.m, probably 300sq.m, not least because their performance appears to be less effected by weight than other styles (because their substantial camber allows them to fly at a higher angle of attack then other styles?). • Ram air inflated kites of the bridled or arc type are better still and can probably scale to 500sq.m or more before weight/area becomes restricting, perhaps quite a bit more. • NASA style frameless single skin multi-bridle kites could be built to at least 250sq.m and probably to 1000sq.m or more but their L/D (+/-3) limit's their usefulness to reaching and downwind courses when sailing against conventionally rigged yachts (although because they fly so well in very light winds, they can be competitive upwind against high performance kites in very light winds). • Outleader style single skin frameless 4 bridle kites of 450sq.m are completely successful. 1000sq.m seems possible without their becoming either too fragile or unmanageable, maybe even more. Unfortunately their L/D is lower even than for the NASA's, making them incapable of useful upwind sailing. • Most promising hope are the aeroplane form kites currently being developed for kite energy projects, Rigid carbon fibre structures, they have huge depower, excellent control (by servo controlled surfaces) and should be able to achieve L/D's above 15. Notwithstanding their high weight/area ratio, because of their high L/D, they can fly in very light winds provided they are constantly figure-eighted."	Before starting on the design of a boat be sure that it will be practical to construct a sufficiently large kite for a boat of that size.

Challenge	**Response**
10.6 "The max-min problem" (ref: http://peterlynnhimself.com/Kites_For_Yachts.php) The biggest challenge in the development of kitesailing is the, variously called, max./min. problem. This problem is caused by the maximum kite pull for any given wind being 5 to 25 times that of a similar sized conventional sail in the same conditions, while it's average pull will be about the same. 20 sq.m kites are generally flown on lines of 30m or so and larger kites require even longer lines- whatever the minimum length is to get the kite clear of turbulence, to give it room for manoeuvre, and sufficiently above the waves to reduce the likelihood of accidental immersion. At these line lengths, kites will at times accelerate to a maximum apparent wind speed that is … [approximately] the true wind speed multiplied by the kite's Lift / Drag ratio. • For example, in a true wind of 20km/hr and for a kite of L/D 5, max. kite speed will be 100km/hr- at which speed it will theoretically develop 25 times as much pull (it's a square relationship) as it will at steady state in 20km/hr, or 11 times the pull at 30km/hr, the likely apparent wind speed for an upwind course on an average sailboat in 20km/hr true. Actually in practice it's not quite this vicious- but is still quite bad enough to make kitesailing difficult and potentially dangerous. It is almost impossible to design a kite, rigging, attachment system and even to build the boat itself strongly enough to take this level of overpull without breaking. … By very careful and skilled kite flying it is usually possible to prevent the kite 'getting away' to its max. apparent wind speed. The operative word here, unfortunately, is 'usually'. In turbulent conditions, through momentary inattention or in even minor emergencies it is inevitable that the kite will occasionally accelerate to its max. speed / max. pull. In anything except zephyr winds, the result of this will be structural failure of the kite, line, rigging or boat, with considerable risks to crew- or the boat itself will be catapulted into the air, with no certainty of coming down in one piece or necessarily the right way up. … There are some ways to mitigate this max/min problem other than by perfect kite control though:	An autormatic load limiter system has been designed for incorporation into the *WINDFLY Rig* to limit the maximum load which may be generated by the kite.
Gust Response: One is to build automatic de-powering systems into the kite. Automatic de-powering is generally called gust response. • the framed delta style traction kites we used for kitesailing in the late 1980's were intrinsically very good in this respect; their pull increased at only about half the rate of the underlying theoretical square relationship between wind speed and pull. • Current Arc style soft kites have good gust response. • Bridled 'foils and NASA style single skin frameless kites have almost no gust response. • LEI (leading edge inflatable) kiteboarding kites have some gust response. • Aeroplane style rigid kites (including 'Box' kites) can have excellent gust response if the angle between their front and rear surfaces is made to be proportional to line pull. Very many automatic pull mitigation systems have been tried in the more than 175 years during which kites have been developed for sailing applications, but except for suitably rigged aeroplane style kites … [none] have yet proven to be satisfactory in practice. A problem with many of the systems that have been tried is surging or pumping; Harmonic interaction between aerodynamic forces and flexible or responsive elements. This, at least, costs performance and is unsettling for the sailor(s)- but can be destructive and even dangerous if a runaway increase in the amplitude of surging occurs.	An automatic load limiter system has been designed for incorporation into the *WINDFLY Rig* to limit the maximum load which may be generated by the kite. Instead of modifying the kite to limit the maximum load, the load limiter system incorporated into the *WINDFLY Rig* is placed on the mast and boom and automatically extends the control (rear) lines to limit the maximum kite load.

Challenge	Response
10.6 "The max-min problem" (continued) *An advantage for lower performance kites:* A limited answer to overpull is to use kites with lower efficiency- because their maximum pull will be only 5 to 10 times their average rather than the 25 times or more of high performance kites. Examples are NASA wing style soft kites and the Outleader style developed by Dave Culp / Dean Jordan, for the 2003 America's Cup contest These kites are only useful when sailing downwind and on broad reaches. NASA and Outleader style kites are however generally useable even on boats that have not been specifically designed for kitesailing- and the Outleader has developed some market as a spinnaker replacement. In very light winds, the NASA type has useful upwind performance when compared to other styles of kites that are used for kitesailing. The reason for this is that, because of their highly cambered form, NASA's develop strong pull even while hanging at their maximum angle to the edge even in very light wind- whereas higher performance kites require to be 'figure eighted' in these conditions, thereby losing much of their effective upwind angle.	It is not a preferred response to use kites with lower efficiency since this makes it more difficult to make ground to windward.
Safety Release Systems: A total but sometimes inconvenient answer to the overpull problem is to build in an automatic (and/or manual) release system that either releases the kite completely (not so safe for anyone downwind though and requiring later recovery in any case) or half releases the kite so that it will collapse on to the water while still attached to the boat. Release systems work provided they don't have to be used too often- the idea is not to spend half or more of your total sailing time doing retrievals and relaunching- but are a useful and necessary fall back when used in conjunction with other overpull mitigation systems.	An emergency quick release system has been designed which may be incorporated into the *WINDFLY Rig*.
Flier Control of Pull: The other major way to mitigate the max/min problem is volitional pull control, usually called de-power. By this, the kite's flier has some control over how much pull the kite will have at any instant. It is generally accomplished by changing relative line lengths- conventionally by reducing the tension on rear lines- but can be by other means. For single line traction kites (such as the Arc used by Delft University in their kite energy program) it is by servo control, for aeroplane style kites, de-power is effected by changing the angle between the main wing and tailplane. For kite boarding kites, power control is often called 'sheeting'- a term borrowed from sailing. Until about 2005, the maximum de-power generally available was around 30%- that is, when a kite is sheeted to max. power, the flier could choose to reduce it's pull to 70% or a little more. Each of the major styles of traction kite has been vying for the lead in this prized characteristic, but LEI's are currently the clear leader with their 'Bow' or 'supported leading edge' style and 5th line systems. Bow kites can be de-powered by as much as 75%, albeit with significant loss of control towards this end. 5th line LEI's depower nearly 100%, but are not steerable when flown off their 5th (de-power) line.	Flier control is unlikely to be sufficient by itself. An automatic load limiter system has been designed for incorporation into the *WINDFLY Rig* to limit the maximum load which may be generated by the kite. The load limiter system incorporated into the *WINDFLY Rig* is placed on the mast and boom and automatically extends the control (rear) lines to limit the maximum kite load.

Challenge	Response
10.7 "It is difficult to manage the lines when they go slack" *(ref.* http://peterlynnhimself.com/Winch_Systems.php) A fundamental problem is that lines are tension-only elements; you can pull them in but you can't push them out. This matters because very often when kite flying, one or all of the kite's lines will sag [and] go completely slack. Experienced kite fliers using handles or bars can usually cope with this by anticipating and avoiding it's onset from line tension changes and other indicators, they can pull back very quickly, and they instinctively compensate for the control effects of slack lines - for example, by pulling in more than they would on a tight line for the same response. They are assisted in this by being able to feel how much pull each line is subject to from second to second. Also, for kitesurfers, lines don't hang loose very often because when line tension decreases, they sink into the water, ceasing to move towards the kite, which automatically increases the kite's apparent wind speed and re-tensions the lines. Unfortunately, kite sailing boats don't behave this way, they over-run their kites like crazy given any chance, and if their kite is connected via a winch system, control will be sluggish and insensitive.	A line tensioning system has been designed which may be incorporated into the *WINDFLY Rig*. The line tensioning system takes in the lines if the load falls, this maintains a minimum tension in the lines at all times.
Line snags: When lines between a boat and its kite are loose, sooner or later, inevitably, a line gets wrapped around something on the deck (bad) or underneath the boat around the rudder etc (worse) or around something that isn't part of the boat- another boat for eg.(worst).	Use the line tensioning system to to avoid slack lines: • Adopt user friendly kite design, hopefully also skilful flying, and skilful helming to turn the boat upwind to maintain airspeed during lulls. • And be sure to use kites which are water relaunchable
Winch jams: If a line is wound even relatively loosely onto a drum and then the line tension (when pulling in or letting out) increases substantially for any reason, the tighter line will catch in under the looser turns and snag- often terminally, with complete loss of kite control … if the line between the let-out pulleys and the drums is loose when a drum is letting out, that line WILL snarl and jam. • Using large diameter winch drums with fewer turns helps but doesn't solve these problems entirely. • Using stiffer lines, placing them in tubes, and eliminating as many snag points as possible also helps, • a more comprehensive approach is to make powered (mechanically or electrically) let-out pulleys that rotate faster than the drum when letting out, slower when pulling in so as to keep the lines tight within the winch system. • Another approach would be to put each line in a tube between the drum and its pulley(s), place a seal around the line at the drum end, and pump water into the tube. I did a test of this and found that a few litres of water at just 2 bar (from a bilge pump for eg) is sufficient to quietly 'extrude' the line from the tube- keeping some minimum tension on the line at all times.	Use the methods described above to avoid slack lines. A line storage system has been developed in which the lines are stored in a single layer on a winding drum. A fleet angle compensator is incorporated to adjust the position of the winding drum so that the lines wrap on to the winding drum in a single layer..

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