Supporting cooperative teamwork: information, action and communication in sailing

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Abstract

This paper provides details of an in-depth investigation into how racing sailors use information displays and devices, and shows that these devices act as communication loci and instigators of action. We present a brief summary of the ways that technology has pervaded the environs of sailing yachts, and analyse how this has affected the activities of the crew and altered the relationship between the sailors and their environment. We introduce a taxonomy of information processing levels that allows us to understand what information is currently presented and in what form, and provides a basis for us to consider future developments in the field. We then look in more detail at two example systems developed and deployed on a racing yacht, and consider their impact. They are analysed from the perspective of assisting people to improve their performance in training and in race situations, and the differences between the frenetic race around a course for 2-4 hours that is the standard race is compared to the longer timescales of offshore racing. We use a combination of observation, discussion and personal reflection in undertaking the study.

Keywords: information displays, cooperative work, action, communication, case study, sailing

1 The influx of modern technology

For many, sailing is an escape to the natural world – powered by wind, controlled by physical skill and strength - active exercise in the outdoors, the native elemental forces of wind and water combining to provide exhilaration, excitement, and an escape from the heavily technological world in which we inhabit. Such are the joys of dinghy sailors, racing or cruising inland and coastal waters, and important they are too. But sailing is also in the vanguard of high-tech development. The America’s Cup, the oldest international sporting competition in the world, has 12 international teams, with the biggest team budget estimated to be around $90 million (32nd America’s Cup Official Website, 2006), a substantial portion of which is poured into research and development activities in technologies, materials and designs. This technical approach to sailing has also found its way into the lower echelons of the
sport as well, for reasons of safety, performance or convenience. For most sailors who sail on yachts (roughly, boats that you can sleep on board) recent years have seen a significant advance in the range of technologies that have found their way onto the standard yacht: a typical yacht has become home to numerous embedded and PC-based computing systems. Boats are still fundamentally sailed using the power of the wind to drive the hull through the water, but most environmental variables are now monitored and presented electronically.

Sailing represents an interesting domain for CSCW research. Cooperative work is required on board: a team of people need to work as one in order to drive a yacht around the racecourse, whether it is for a short inshore race of a few hours or for a multi-day offshore race of many miles. Race sailors are motivated to improve their performance, and the increasing technology involved in the sport means that raw data is becoming easier to collect and utilise. It is also a harsh environment, in which the elements conspire with competition to provide an intense, challenging domain in which the focus of the participants is not on the technology, but on the race itself. Close quarter racing requires high levels of concentration, and it can also be physically demanding. Presenting information to people is also non-trivial: there are limited locations to display it, and racers are often short of time to process the data.

The development of GPS has been the most significant factor to impact yacht systems, since it provides a geographic, absolute position for the yacht, rather than the relative systems that were the only things constantly available. In older times, yachts would take dawn and dusk fixes, using astronavigation techniques to determine the position of the boat on the surface of the earth by observing the position of heavenly bodies. It was a skill that required practice, the right conditions of a clear horizon, sufficient light to see it by but not enough to obscure the stars, and with luck a position accurate to a mile or two could be achieved. Alternatively, the easier midday sight could be taken to provide another position fix. Adequate for long-distance racing or cruising, it had to be supplemented by direct reckoning approaches, in which the yachts speed through the water would be multiplied by the time since the last plot, the direction noted, and transferred to the chart. Done carefully and corrected for tidal flows retrieved from reference books, it was possible to navigate from one port to another for periods of up to 48 hours with some accuracy: however, closing a hostile shore in the dark in a serious wind with rain lashing down and very limited visibility, its inaccuracies were all too obvious and potentially dangerous for comfort. Radio systems such as LORAN-C and DECCA provided some advance, using phase detection to identify a position, but receivers were expensive and reliability was suspect, especially in poor atmospheric conditions – just when they were needed. GPS resolved this in one go, and sets became rapidly available at affordable prices. Now the yachtsman could locate their position accurately to within 30m at any time of the day or night, no matter how attentive, or not, the crew had been to keeping the yacht on course. More recently, the past five years have seen the rapid rise of electronic charting, in which the GPS position signal is overlaid on an electronic map of the sea, identifying the yachts position without the need for transferring it to a paper chart. With selective availability now turned off, GPS accuracy has increased to a few metres. Electronic charts have been themselves the subject of rapid development, now offering 3-d perspectives and tide and port information, and are available as both embedded devices or as programs that run on standard PCs.
It is not only navigation systems that have benefited from new technological approaches. Marine instrumentation systems run on a network, with one or more instruments or displays attached to a network cable and addressed by number. All systems support, as a minimum, the NMEA0183 protocol (NMEA, 2002), but tend to overlay that with their own proprietary systems that offer faster data rates and additional information. NMEA presents data in an ASCII sentence, delimited at the start with a $ sign and at the end with crlf, with the intermediary data comma delimited, and runs at 4800bps. A star topology is used, in which one or more ‘arms’ radiate out from a central control box containing the embedded processor. For lower-end solutions, there is a control box embedded into each of the display instruments, so that the wind displays capture whatever data they require to present wind information, the depth displays capture the depth data, and they are individually responsible for processing and presenting it. Higher-end systems provide one or more processing boxes that act as a central point for collecting and processing the data, sending it out to displays, which tend to be multifunctional and able to display any combination of data that the sailors require.

Wireless instrumentation systems first appeared in 2001 when Tacktick launched a range of solar powered, wireless systems, obviating the need for cabling (Tacktick, 2006). And cabling for instruments on a yacht has two major problems. The first is positioning it: most instruments are at the extremes of the yacht – 15m off the sea at the top of a thin mast, down which the cables have to be run, or 12m away in the bows of the ship, necessitating the passing of cables through convoluted cable runs so as not to interfere with the interior accommodation. Once in place, these cables are subject to the vicissitudes of salt and water, not the ideal environment: they corrode, introducing failure points into the system or, often worse, fluctuating errors. Wireless systems are now used not only to transmit data for display, but also to control the system: pioneered by B&G in 2004 (Simrad, 2006), most manufacturers have now added wireless or Bluetooth controllers to their range that patch into existing networks and offer remote control of the systems, allowing the displays to be altered from a distance and providing a portable repeater for some of the key data.

Since the wind is the motivating power on board a sailing yacht, knowing what it is doing is of key concern, and most yacht instrumentation provides measures of the wind speed and direction. Other key information needed is depth (to stop hitting the bottom) and boat heading. Older technical solutions were available for this: depth was sounded with a lead and a line, now almost universally replaced with an echosounder, and boat headings have been instrumented with magnetic compasses for millennia, with electronic fluxgate compasses now starting to make inroads into the upper end of the leisure market. The interesting issue for wind measurement is that it is always relative to the yacht: the wind speed and direction seen on board is affected by the yacht’s existing speed and direction. With the correct level of additional instrumentation, it is a simple task to turn these into absolute measures (i.e. those that would be observed if the measuring instruments were stationary). It is important to remember that almost all sailors have come up through the ranks, and started their sailing in small dinghies and learned to sail without the use of instruments, relying on their own perceptions of the direction and strength of the wind. This means that the innate, learned skills of most yachtmen relate to the apparent wind speed and direction (the observed ones) and not to the true wind speed and direction – what the
wind is actually doing. This has implications for information display, which will be discussed later.

2 Sailing roles

From now on, we will focus on the needs of a race yacht crew: many of the details are relevant to leisure sailors, but racing ones have a stronger incentive and commitment to maximising their performance and the performance of the boat, and our in-situ studies have been with racing sailors for this reason.

This paper presents the results of a long-term study into the use of instrumentation on board a 34’ (10.1m) racing yacht, raced by 8 people. The boat is a X-Yachts X332 cruiser-racer, called ‘Xcentric’, based in Hamble in the Solent, UK. The study was run over a period of three years. The detailed study is limited to only one boat, though the way the participants work together is common across most boats, with minor variations. This is because crew commonly sail on different boats, and there needs to be a mutually understood demarcation of roles and approaches to working together. Most of the crew on Xcentric have raced on other boats as well, and in discussion agreed that the principles and practices identified here would transfer to most other racing yachts.

The author also races, and some of the work results from intensive reflection upon the practices and actions of my own behaviour. In some cases I have been an active participant in the racing whilst also observing the crew’s behaviour and the role of technology: in others I have focussed only on observation and understanding and not played any active role in sailing the boat. In common with other observational and ethnographic studies, much of the information has come from discussions with the crew members as well as direct monitoring of their behaviour (Forsythe, 1999). In addition, we have also studied the effects of technologies on the behaviour of new crew members, both skilled sailors with a set of expectations and competencies, and novice ones, who we are teaching to sail. These provide us with insights into the changes in thinking and cognitive processing that occur in the transition from novice to expert behaviour.

2.1 Roles and responsibilities

A typical race crew on a 34’ yacht consists of eight people, who take the roles described below:

1. ‘bow’ - responsible for attaching new sails on the front of the boat, removing existing ones, and sorting out any tangles that occur at that end of the yacht.
2. ‘mast’ - helps bow with sail attachment and recovery, and hoists the new sails as required by pulling rapidly on the relevant halyard (a rope that leads to the top of the mast and back down again).
3. ‘pit’ (sometimes called ‘keyboards’) - controls all the ropes in the cockpit, particularly the halyards which are led back there from the mast which raise and lower the sails, and the rope clutches that hold sails up once they've been hoisted.
4. ‘trimmer’ - responsible for setting the front sail (called the genoa) correctly.
5. ‘grinder’ - provides the muscle power to winch in the genoa to trim it properly: used extensively when the boat turns through the wind and the sails swap sides.
6. ‘mainsheet’ - sets and trims the mainsail (the largest sail).
7. ‘helm’ - steers the boat.
8. ‘navigator/tactician’ - decides which way the boat should head and which manoeuvres are going to be required.

On smaller yachts with fewer people, some roles are combined, whilst for larger yachts with more crew the roles are subdivided, or have more than one person assigned to them. We focus on yachts with around eight crew for two reasons: the first is that the eight roles are consistent regardless of the size of boat and number of crew – in combination, they allow all the main actions necessary to race the boat to be achieved. Secondly, eight crew is typical for a racing boat that undertakes both inshore and offshore racing.

Xcentric, in common with the majority of other race yachts, allocates the crew into these roles directly if there are eight sailing; if there are only seven people on board, either the helm and navigator roles or the navigator and bow roles are combined. In addition, the trimmer and grinder roles are sometimes shared between two people, who exchange roles each time the boat is tacked (when it is turned and the sails swap sides). This allows the physical load to be shared between them – the role of grinder is intensely physical, requiring a burst of power for between fifteen seconds and two minutes, turning a winch to bring in the sail.

Each of these people requires different information in order to perform their roles effectively. Boat speed is useful to all, but whilst trimmers are keen to seen the effect of their adjustments in fine detail, the navigator may be looking up the course for increased wind pressure to increase the speed.

Xcentric races at club, national and international level, and is reasonably successful, having won at national level and been in the top five internationally. However, all the crew are keen amateurs, with no professional sailors amongst them. They comprise both men and women, with a core team of four or five taking the more critical roles (helm, mainsheet, trimmer, bow, tactician) with less regular participants filling the other roles. It should be noted that yacht racing comprises a series of highly choreographed manoeuvres performed at high speed, followed by a settled period in which much less is actually adjusted, and most of the crew sit on the upwind, high side of the boat (called the ‘rail’) to add leverage. The active people are the helm, who is constantly adjusting the course of the boat to maximise its speed through the water, taking into account the effect of changes in the wind and the waves, and the tactician, who is always reassessing their perspectives on the best route to take, given the tide, wind conditions, and boat-on-boat tactical considerations. The mainsheet trimmer is also permanently involved in the discussions and trims the large main sail fairly regularly. The genoa trimmers are occasionally needed to adjust the set of the front sail as the conditions alter – in light, changeable winds they may be altering the set of the sail every 30 seconds or so, through to once every 5 minutes or so in fresher breezes, with stronger steady winds meaning they may not have to alter things once it is set up – though checks will still occur every 10-15 minutes.

The team was observed in both training and race modes. In training, one manoeuvre is picked upon and an activity created to focus on that particular skill, or a very compressed course is sailed, in order to focus on a range of manoeuvres. For many of the training exercises, the crew were happy to report on how they used the
instrumentation and could be questioned freely. In a race situation, they were focussed on the task in hand and were not able to discuss the details of what they were doing until the activity had settled. Reflection and discussion to and from the racecourse, and in the bar afterwards, formed an integral part of the discussions, as well as the observations at the time.

3 Technological baseline

One of the interesting features of yachting as a domain is that it is difficult to put the displays in locations that all can see them. Typically they are placed across the companionway in the centre of the boat, facing to the rear, though there is usually only space for two or three displays, allowing four to six pieces of information to be provided. Current race boats now augment this by putting additional information up on mast displays (i.e. facing the rear of the boat but placed in front of most of the sailors), with large numbers repeating a variety of information (see Figure 1).

![Figure 1: Location of instrument display on Xcentric](image_url)

The initial setup on Xcentric was as follows. Transducers allow wind speed and direction to be captured from a carbon fibre wand at the top of the mast, a fluxgate compass adds magnetic heading, and a GPS provides absolute positioning information. In addition, boat speed and water depth transducers complete the data feeds into an embedded processor (a B&G Hercules device). This is dedicated to performing all the necessary computation, with the outputs being networked to four displays: two multi-function displays are placed above the companionway, in front of the cockpit: they can be seen by the cockpit crew (helm, mainsheet, tactician, and
trimmers when they are by the winches) but not by the crew on the rail. These can each display two pieces of information (Figure 2, left). In addition, two further displays are placed on the mast: each present one piece of information at any one time, in large numbers that are visible to all members of the crew. Xcentric uses 20/20 displays on the mast, large enough to be easily visible to all crew (Figure 2, right).

In addition, the raw data is output from the Hercules box into a PC running dedicated race software, which allows it to display any of the calculated data but is primarily used for electronic charting, displaying the GPS position overlaid on an electronic map.

4 Instrument information processing taxonomy

The data available ranges from raw detail e.g. boat speed, apparent wind speed and angle (the wind felt by the crew on the boat, affected by the boats motion), through to derived data (e.g. true wind speed and angle – that which a stationary observer would measure, i.e. corrected for the boats motion) and highly processed information (e.g. percentage performance compared to the optimal, the angle the wind will hit the boat on the next leg of the course). Much of this information is relevant only to certain people at certain times, and it becomes part of a crew's training to learn which displays they need to look at and when. A crew's role and current context are relevant: people have different information needs at different stages during a race.

In order to understand the levels of instrumentation and hence technological assistance that the sailor is receiving, we have developed an information taxonomy, presented in Table 1 (Beale, 2005).

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<table>
<thead>
<tr>
<th>Level 0</th>
<th>No instruments</th>
<th>Personal feel, intuition, etc. Common in dinghy sailing, can be very effective if well trained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Direct</td>
<td>Direct readings of boat speed (spd), apparent wind direction (AWD), apparent wind angle (AWA), apparent wind speed (AWS) magnetic heading</td>
</tr>
</tbody>
</table>
```
<table>
<thead>
<tr>
<th>Level</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Processed</td>
<td>Process level 1 data with level 1 data to give true wind speed (TWS) and true wind angle (TWD) (by combining AWS, AWA, spd, dir) plus VMG (vel + AWA))</td>
</tr>
<tr>
<td>3</td>
<td>Add electronic fluxgate compass</td>
<td>Provides usable direction data – combine to give true wind direction (TWA + dir)</td>
</tr>
<tr>
<td>4</td>
<td>Add GPS</td>
<td>Provides course made good (CMG), speed over ground (SOG), VMG to waypoint</td>
</tr>
<tr>
<td>5</td>
<td>Process data with GPS</td>
<td>Provides tide/current velocity (speed and direction) from boat through water c.f. over ground.</td>
</tr>
<tr>
<td>6</td>
<td>Computer storing/presentation of data</td>
<td>Provides maximum performance figures &amp; GPS chartplotting.</td>
</tr>
<tr>
<td>7</td>
<td>VPP/polars</td>
<td>Provides design data on predicted speed and optimal angles to sail upwind and downwind. Tidal and weather prediction-based routing.</td>
</tr>
<tr>
<td>8</td>
<td>Trim</td>
<td>Represent technical information in more usable form (% off optimum), trim or point/bear off</td>
</tr>
<tr>
<td></td>
<td>Add graphics</td>
<td>Provides history information – allows level 0 predictions/understanding.</td>
</tr>
<tr>
<td>9</td>
<td>Tactical</td>
<td>Add interpretation – current wind shift information, trend.</td>
</tr>
<tr>
<td>10</td>
<td>Strategic</td>
<td>Longer-term race strategies, including prediction – when to tack, duration of shift, routing via windshifts. Also trim advice.</td>
</tr>
</tbody>
</table>

**Table 1: Information processing taxonomy**

Each level requires more processing or input than the level before it, and each later level requires only the data in levels below it. This taxonomy provides us with a way of classifying the different levels of computational assistance on board a yacht, but it also reflects the penetration of technologies into the professional and leisure yachting domains. A dinghy has level 0 information, whilst a small yacht has at least level 1. A standard equipment level for a contemporary cruising yacht is at Level 5, whereas a competitive race yacht will have instrumentation available up to Level 7, possibly level 8. Level 9 is available in a basic form on the more advanced yachts, with level 10 being the current research domain, not found in professional or leisure markets, but no doubt under consideration by the America’s Cup syndicates (Rusch, 2006).

The major studies conducted on Xcentric were conducted with the sailors having access up to Level 7 information, and are primarily concerned with inshore racing, in which the boat is sailed around a course in a race lasting from two to five hours. Top boats often finish within seconds of each other, meaning that optimal performance at all times is critical, and the frequency of manoeuvres mean that most time is gained or lost when boats come together to round marks in the course.
5 Instruments as the focal point of action and communication

Observing the crew racing on the boat, we can see that their roles fall into two major categories. In the first category are the helm and the tactician. These two are permanently active, with most of their physical and cognitive effort focussing on the race (they are colloquially known as the “brains trust”). The mainsheet trimmer is also permanently active, but works in conjunction with the helm and responds their instructions or to changes in wind pressure: whilst being fully occupied, their focus of attention is localised on just trimming the main sail and they need have very little situational awareness, unlike the other two.

5.1 Helm and tactician

The helm is steering the boat, deciding how to work it through the waves and keeping an eye on the trim of the sails: they tend to notify the mainsheet trimmer and when necessary the genoa trimmer that changes need to be made, either in response to environmental changes or to course alterations. To assist them with this, the helm uses four main pieces of information: the boat speed through the water, the true wind angle, the true wind direction and the true wind speed. True wind speed is used as an index into a table which identifies both the optimal angle to sail to the wind when going upwind or downwind along with an expected speed (together called the ‘polars’), and the helm constantly monitors these to ensure that the boat is performing. The boat is usually steered at the optimal angle, with the sails trimmed to achieve the polar speed (or higher). Thus, the helm requires easy access to both the true wind angle, and the boat speed, and these are displayed on the large displays on the mast, allowing them to be seen no matter how crowded the cockpit becomes. The other wind information is displayed on one of the multi-function displays over the companionway. Sailing the boat at its optimum angles and then maximum speed is of such critical importance that the helm is often asked to ‘sail to the numbers’. In this case they tend to set the boat up and steer it using primarily the true wind angle (level 2 data) which they modify with level 0 data to account for the waves and minor changes in pressure and direction.

The navigator/tactician is working out where to go and how to get there, and how to avoid the other boats in the process. For some races when the fleet distributes itself, this task is one that can be undertaken sporadically, but it is clear that it takes practice and, usually, local knowledge of the sailing area if this is to be successful, since there is a lot of contextual and ambient information that the tactician needs to be aware of all the time: what the tides are doing currently, what they are about to do, where the other boats are, where to go next, what the wind has been doing and what it’s predicted to do, and so on. This is clearly constantly changing, and if the task is suspended for a while there is a delay whilst the previous status is updated. It is sometimes the case that very poor decisions are made, from a race outcome perspective, just because one piece of information has not been correctly updated in the tactician’s thought processes, which has a major impact on the overall result. To assist this, the helm and navigator often keep up a conversation about the conditions, current tactical situation, and their plans for the short and longer-term. The tactician needs to maintain an awareness of the wind, and so requires true wind speed and true wind direction to be displayed. The wind usually oscillates, swinging gently up to 15 degrees either side of its mean direction, and effective use of these swings offers great
advantages to the boat. The tactician assists in feeding back the optimal angles to sail to the helm, and also works with the trimmers to notify them when the sails are not set for optimum efficiency. Tidal information changes all the time, but usually the tactician works from a paper-based tidal atlas, which gives details of the flows in the sailing area, and updates their information on an hourly or half-hourly basis. In very light wind conditions when the tidal stream is proportionally more significant, one of the multi-functional displays is switched to display the speed and direction of the current tidal conditions the boat is experiencing, so that it can be navigated into the optimal part of the tidal stream. Otherwise, the display usually shows a repeat of the boat speed and the current depth, necessary in shoal waters sailing, or it will display the range and bearing of the next mark. This does not relieve the navigator of the responsibility of spotting the next mark, since it is usually not possible (or desirable) to sail directly to it (boats cannot sail directly into the wind, and do not go their quickest directly away from the wind, and marks are often set directly upwind or downwind for just these reasons). However, it provides information to the helm about how far away the mark is, and roughly where it is in relation to the boat and its current heading. This reduces the need for communication, which whilst useful to retain context can be distracting.

It can be seen from this description of the roles and information usage of these two participants that the instruments form a focal point for their interactions. As situated displays (Suchman, 1987), they form an integral part of the operating environment, and take their meaning and significance from their context (Streitz, Röcker, Prante, Stenzel, & van Alphen, 2003). The data presented is the focus of the conversation and their subsequent actions (Goodwin, 2000): the helm will stare at the true wind angle for potentially hours at a time, focussing on keeping the boat at its optimal angles. The navigator will be assessing more pieces of data, constantly monitoring them for changes. For the true wind direction, he also keeps a mental note of the historical values and so can see when the wind is shifting one way or the other. 5.2 The rest of the crew The remainder of the crew are intensely busy during manoeuvres, especially turning round the marks of the course (called buoys), but spend much of the rest of the time at a cognitively reduced level of engagement. Their roles do not require them to be fully aware of where the boat is in the fleet, whereabouts on the course it is, or what the conditions may do in the future. They sit on the high side of the boat, legs over the side, putting their weight to maximum righting effect, but are not called upon to directly contribute until the next manoeuvre, which can be anything from a few minutes to almost an hour. Even then it may be a simple tack, when their main role is to move across the boat onto the new high side as the sails come over, and little engagement with the whole contextual situation is required for them to achieve this effectively. Depending on the level of the racing, and experience of the crew, they will attempt to remain engaged, especially with the conditions, assessing the wind strength, assessing the next likely manoeuvre and when it is likely to happen – or will temporarily switch off and discuss their social lives or other things not related to racing – or may retreat into a semi-catatonic state, especially in cold, wet, endurance-type conditions.

These people use the information presented in a different way. It is used as a rapid measure of key variables, allowing them to rapidly re-engage with the race when
action is needed or imminent. Boat speed is used to check that the boat is still going at or near maximum speed: most of the crew build up knowledge of what numbers to expect to see there based on the current conditions. They obtain a measure of the current conditions from the true wind speed, as well as observing what is happening on the water around and ahead of them – converging on other boats, a buoy, or the shore are all indicators that action is likely to be necessary in the near future. If the range and bearing to the next mark is displayed, that information is often used as a measure of the likely delay: if the buoy is a number of miles away then they know they are not likely to have to swap sail for at least 30 minutes, whereas if it is a few tenths of a mile then they need to be preparing for action.

As buoys are approached, the crew need to coordinate with the tactician and helm to decide on which manoeuvre will be used, and which sails will be used. Experienced crew are able to assess most of these details from the data displayed, whilst less experienced ones have to have the decisions relayed to them.

For the crew, the instruments provide a gateway back into the race, allowing them to conserve their mental energy until it is needed. In addition, the more experienced ones can use their knowledge to assess the likely manoeuvres and sail choices based on the environmental information received.

The genoa trimmers are called upon when the helm or tactician feels that the boat is not performing properly, either through instinct or via comparing actual to predicted performance with the polar figures. In these circumstances, the trimmer moves from the windward side back into the cockpit and then adjusts the sail as necessary. In these circumstances, they use the wind speed and direction to provide them with key information, they factor in the state of the sea which they have observed, and discuss with the helm and tactician the trim options that exist and what should be adjusted. Boat speed is the key number: it indicates immediate success or failure in the changes, but has to be monitored to understand whether the overall effect is beneficial. For this reason, boat speed is one of the key information factors and has to be presented where all can see it easily; hence it is placed in prime position at the top of the mast displays, unobscured by people in the cockpit.

But even with mast displays, it is often the case that it is hard for all crewmembers to see the information, and even if they can see the displays, the fact that they each need somewhat different information often makes it an impossibility to show these in the reduced space available. It is also important to realise that the interaction that occurs is between the sailors, not between sailors and the instruments, and that the sailors have a particular role to perform (Bardram, 1998). This role requires most of their attention and physical effort, informed by the information they can gather from the instruments, but it means that they are paying sporadic attention to the displays. This provides them with one of their key problems: the context of the interaction is critical and, because of their fragmented attention, they often return to viewing the instruments without knowing the full context of the interaction and then have to infer it. The information presented to the sailors provides them with information about the environment and, to an extent, the actions of others and the actions expected of them: this has similarities to the use of displays to present awareness information in other distributed working contexts (Cheverst, Fitton, Dix, & Rouncefield, 2002; Dourish & Bellotti, 1992; O’Hara, Perry, & Lewis, 2003).
5.3 Removing instrumentation

We can compare this use of the data and the conversations it facilitates to that experienced when there is a much-reduced level of instrumentation. We observed this happening in two different scenarios: the first was in a training exercise, when the displays were deliberately obscured, whilst the second was during a number of races when then calibration of the system had been adversely affected and the wind instruments were active but providing incorrect information. In the training exercise, the whole crew were initially more engaged, but found that, without the data available, once the contextual understanding of where they were and what they were doing was lost it was harder to re-establish. In the race situation, it took a long while for the helm to accept that the instruments were incorrect, despite the boat falling behind and sailing in different directions to other yachts. Once accepted, the crew reverted to sailing on Level 0 information – their natural skill and experience, and found that the boat performed almost as well as with the full range of instrumentation. Both helm and navigator reported feeling less stressed as they felt they had less information to deal with, although the boat was fractionally slower overall.

5.4 Offshore Racing: differences

In offshore, or ocean, racing, the courses are usually much simpler – from one port to another, for example, but are much longer – 18-36 hours is typical, but they are frequently longer. On such a race the manoeuvres are much less frequent, the level of activity has to be moderated so that it can be sustained for longer, and the crew have to manage their eating and sleep needs as well as the needs of the boat. Each manoeuvre tends to be less critical than in an inshore race, but the strategic decisions about which way to sail become more critical. In these circumstances, the on-deck information needs tend to be very similar, but the tactician spends more time below with the computer, assessing routing options, deciding how to position themselves to take advantage of changes in the weather over the forthcoming hours or days, and analysing straight line performance to ensure that nothing is being lost in direct speed.

6 Information requirements and perceptions

The tactician and the helm report that the current level of instrumentation provides them with all the information that they need. The navigator needs to alter the displays on one of the multifunctional devices occasionally, but in general the information presented remains the same at all times. All crew reported that the consistency of information presentation was key, in that they would look in particular locations for the data and would not read the labels: mast information was always expected to be boat speed on the upper display, and true wind angle on the lower one, for example. We experimented with changing the location of the information, and found it introduced confusion and errors into the boat handling, though over time people would adapt to the new situation, as we would expect.

One of the tacticians comments on the mast-mounted display as follows:

“Two main benefits: (i) being able to show the information required for the type of sailing we were doing; (ii) and showing the information clearly to the crew.”
They clearly recognise it as useful for themselves, and for contextualising and communicating to the remainder of the crew.

The navigator supplements this on-deck information with two other sources: they utilise paper-based tidal flow atlases and charts, and use the computer below decks. The below-deck PC provides access to up to Level 9 data with a much wider variety of display options. We found it had two main uses: the first is in the pre-start phase, the boat collects environmental information and this can be used to provide useful strategic data for the race. In particular the mean wind direction can be plotted, and his a characteristic oscillating trace, and provides the tactician with information as to the overall mean wind direction an the extent and duration of the oscillations on either side. This allows the helm and tactician to increase the chances of the boat being at the right place on the start line for the shift, and to keep in phase with them as they work their way around the course. During the racing, Xcentric often found that the helm was tracking the wind direction mentally by watching the true wind angle readout, and remembering the trends, since the tactician was either too occupied with other navigational tasks, or had switched to another role and was not available to call the changes.

Direct comments from tacticians and helms echoed the usefulness of the laptop:

“PC based navigation is much quicker than the manual equivalent. You can see exactly where you are without having to plot a position on a chart. Very useful in short race situations and when entering unfamiliar territory.”

“The Seatrack race navigation software had a mass of valuable information including those that I found particularly useful: real time wind direction with tack and gybe angles clearly showing lifting and heading courses; wind direction and strength trend graphs; courses – and the software would give you an estimate of the apparent wind angle you experience on a future leg – very useful in making timely sail selections in advance of a later leg of the course.”

The remainder of the crew tended to feel that their information needs were less well met. If a top-flight crew were on board, the problems were reduced: they stay focussed more effectively, and retain an awareness of the conditions and the progress of the boat around the course – the conversations pertain to sailing and the race and the upcoming situations and manoeuvres. However, for a crew of slightly lower standard, retaining concentration for the duration of a four or five hour race is not easy, and they find that they lose their awareness. For them, there was usually enough information to key them back into an appreciation of the environmental conditions, supplemented as they are by direct observations of the waves and water, but it was more difficult to understand the position of the boat on the course, and in particular to assess what the next manoeuvre was likely to be and how to prepare for it. This was resolved on Xcentric through structuring the communication about this: typically the bow person would be informed by the tactician that they needed to start to prepare, and the bow would gain an initial situational awareness and then pass the information to the rest of the crew, discussing it with them until all were clear as to the expected course of action.
6.1 Displays as educational mediators

We have seen that there is key information that is demanded by the crew of the boat, though there are two types of need and use that it is put to. We have also seen that the displays act as the focal point of communication between the sailors, providing them with a shared reference around which their discussions can be based.

This use of information, as a catalyst for communication, can be seen very strongly when new people are inducted into the race crew. Initial assessments are done on their innate sailing ability and awareness, and they are then allocated a specific role, and a mentor to support them. The instruments form an integral part of them learning to do their role, especially if they are trimming. The improvements to boat speed are immediately apparent to them, whilst the relationship between the true wind readings and the changes necessary in trim or sails to accommodate them take more time to understand. In these early stages of their training, the new crew members move from Level 0 instrumentation through to Level 2 quite rapidly, and have a tendency to become fixated on the numbers and to ignore their instincts. A step-change in performance occurs when they learn to utilise the information but to incorporate it into an enhanced situational awareness rather than as a goal on its own. As one of the more experience crew remarks (sic):

"Less experienced sailors would tend to rely too heavily on the technology slavishly ‘following the numbers’. Digital displays are perceived to be very accurate, in reality there is always a level of error which depends on the circumstances. The technology used as an additional input for sailing is very useful, there is a danger that the technology can become a distraction."

The technology on board can provide a reference point, and a common language, around which knowledge transfer can occur. A mentor can instruct a new crew member to adjust something until a number changes to a set value, providing a quantifiable measure for activities that are essentially skill-based and which require a deep level of knowledge to properly understand and analyse. Even for expert crew, the technology supports them in sharing roles, as they can pass on the details of their activities in terms of a few key parameters that are mutually understood, rather than with a detailed description of the task they are doing and the issues they are having. For example, they can say “take over trimming the spinnaker for me: we’re at 140 degrees polar, wind is 10 knots, with gusts of 15 every few minutes” and that will allow the new trimmer to understand that the helm will be steering quite an erratic course as he adjusts the boat to account for the changing breeze, which may otherwise go unremarked and have catastrophic effects as the helm changes course and the spinnaker collapses, or overpowers the boat.

7 New system design and development

In conjunction with the race crew, we have devised and evaluated alternatives to the standard system in order to understand more about the crew’s use of information and technology in the race situation.

A Brookes & Gatehouse Hercules system (B & G 2000) forms the basis of the system. This measures raw information and provides a fairly comprehensive set of processed results from its two-box processing system. This is augmented by feeding the data into a laptop computer. The laptop allows us to either use standard tactical race
software to calculate more advanced information, or to use our own bespoke processing to provide alternative information. The laptop runs an 802.11b wireless network, with encryption, that allows us to connect a number of wireless devices. The overall system architecture is shown in Figure 3.

The largest display is a colour trans-reflective LCD touch sensitive screen, approximately 19cm (8.5") diagonal, which provides a full screen echo of the below-decks laptop screen. The laptop can be fully driven by the screen, allowing full access to the functionality of the software systems. This setup effectively extends the conventional instrumentation of a race boat by adding in the wireless network and hence deck-based repeating of previously below-deck information, and has been independently adopted by the leading manufacturers for the high end race boats, though it has not found its way onto yachts in the size range we have been considering (around 10-12m) yet.

![Figure 3: Bespoke system architecture](image)

There were three main motivations for extending the system. We wanted to investigate whether any alternative information should also be displayed; we wanted to investigate the efficacy or otherwise of alternative representations of the same data; and we wanted to investigate the possibilities of providing context-sensitive portable devices to each of the crew to allow them to access information relevant to their needs whenever they wanted to.

For the third item, Compaq iPaq's with wireless cards were used. These devices are intended to provide each crewmember with personalised information. Each device knows the role it has to perform, and so can access relevant information and display it
in useful ways for each of the different roles (Gellersen, Schmidt, & Beigl, 2002; Schmidt, 2000). To achieve this it accesses either the bespoke server on the laptop and processes the relevant data, or acts as a secondary screen, presenting laptop information on deck. However, we abandoned this, since the devices were unsuitable for presenting the information to most of the crew: they didn’t have time or room to handle them. Understanding what information could be presented, and when to present it, was rendered possible by the analysis described earlier: the devices had to provide sufficient contextual information to alert the crew prior to them becoming active in a manoeuvre, and to allow them to understand the environmental conditions in sufficient detail (Beale, 2002). Showing the progress of the boat and its location on the course was also requested. However, the physical issues involved in handling individual devices rendered them worse than useless, as they compromised the crew’s ability to perform their tasks, and this part of the development was suspended, with very little development done.

The mobile screen was investigated in two scenarios: the first had it fixed above the companionway, between the two multifunction displays (refer to Figure 1 to see the space). The second had it in the hands of the tactician, stored in a case hanging on the stern (back) of the yacht. Our initial hypothesis was that this would prove to be exceptionally useful, bringing the enhanced processing power of the laptop, with its additional representations and functionality, up onto the deck and into the heart of the action.

The results are best summarised in this quote from the notes of one of the crew after they had been asked to reflect on the systems:

“What didn’t work: Wireless screen. Slightly unfair to say that it didn’t work at all, but generally it didn’t really help that often. The wireless screen required that there be a free crew member to operate it which in a race situation was rarely the case. If there was someone free it was just as easy for them to go below to look at the information at the chart table. Other problems, the battery life was too short to be really useful, the screen was hard to read in sunlight.”

My personal notes, written just after an offshore race, suggest that the system wasn’t a complete failure:

“As I lie in my bunk at 2 in the morning, I can hear the rush as the water races past outside the hull, the occasional creak of the winch above my head, and the crisp-packet rattle of the sails as they shudder in a gust. I reach out for the wireless screen, and turn it on. It shows an image of the PC screen 12 feet away at the navigation station - I can see our position overlaid on the electronic chart. Using the touchscreen I can control the PC, and I switch from the navigation programme to our performance one. This takes boat performance data received from the instruments, and represents it graphically to give an immediate view of how efficiently we’re sailing the boat. Logging performance over the past year has built up a profile so that we can see where on the performance curve we are. Boatspeed seems to be down - I drill down through the general representation to the actual data, and see that we’re sailing too close to the wind, and that with the current conditions, we need to change to a slightly bigger headsail. I open the porthole near my head, and mutter to
the on-deck crew, racing the boat through the rain. The on-watch mate gets the message, groans, and then begins to order the crew to change sails and alter course slightly. I smile, roll over in my sleeping bag, and fall back asleep.”

The mobile screen also proved itself very useful when navigating in unfamiliar waters, acting as a mobile electronic chart plotter, meaning that a lightly-crewed boat did not have to lose one person down below to keep a track of their position but could see it instantly. But as an aid to racing, it failed to improve performance, and whilst it brought information up to the tactician on the deck, it required too much individual attention and was not able to act as a conduit for further conversation and discussion with the rest of the crew. Most information that is rapidly changing and hence needs to be accessible on deck is also of relevance to others in the crew, and focussing it into one device that requires effort to drive does not improve the flow of information around the boat. Informal discussions with crews on larger boats suggest that if there is a surfeit of people, it can provide some benefits to the navigator, but they need time to discuss the new information with others in the boat as well. On a standard size race boat such as Xcentric, the benefits are less apparent.

Fixing the screen above the companionway moves the information back into the public realm, able to act as a catalyst for discussion. Its more advanced graphical capabilities suggest that it could offer useful additional information, and we investigated two alternatives.

The first used the tablet to show the historical trends of wind oscillations, removing the need for the tactician or the helm to constantly monitor and remember the true wind angle. This was well received by the helm and tactician, but the restricted viewing angles on the screen and its poor performance in direct sunlight meant that the graphs were not legible from the usual sailing position of the helm, for whom it is the most critical. By moving from their usual position, the tactician could observe it, but the oral feedback to the helm of the graph was felt to be no more effective than the helm monitoring the raw numbers on the multifunction displays. Presenting this information graphically is of tactical and strategic benefit, and most helms and tacticians on the boat agree that if it were simply to read, it would be a useful addition: one of the next phases of work is to provide an effective and visible representation of this trend data.

The second approach used the display to present Level 8 data and above. In essence, these are highly processed representations of the much lower level, rawer measurements, giving, for example, the percentage of optimum performance currently achieved, or the predicted angle to turn the boat through the next time it is tacked. This information was of particular relevance to trimmers, and provides a rapid way of assessing whether everything is working well at any moment in time. Some of the crew reported that despite representations of overall performance being cognitively easier to process than the five or six separate items of data they are used to seeing, they reverted to using the raw information. The display transpired to be much less effective and accepted than we predicted. Whilst it would show any drop in performance, the sailors needed access to the lower levels of data in order to understand why it was happening and hence to be able to correct it. It therefore acted as a trigger: but competitive sailors would always be performing those checks
themselves anyway, and so its information tended to be redundant. Less experienced racers found it initially appealing, but soon found that the useful, actionable information content was low, and began to ignore it as well. Even using it to present the polar figures (the optimal benchmarks in performance) was less useful than we envisaged. Polars change all the time with changes in wind strength, and it was thought that having the instantaneous polars always available would allow the helm and trimmers to know exactly what they were aiming to achieve. However, the fluctuations caused by changes in boat speed, wind strength, boat motion through the waves, and so on, meant that the values displayed changed with great rapidity, and required mentally smoothing and averaging to turn them into usable information. It was easier to use the previously assessed wind strength to index a table to provide a guide as to the polars, and change that whenever a substantial change in wind pressure or sea state occurred.

This demonstrates that there is a strong relationship between the update frequency of the data and the rate at which the sailors can adapt their actions in response to it. Changing it too rapidly means that they have to expend cognitive effort smoothing it, and often resort to other resources that provide them with the same information at the appropriate frequency. Information is not merely data that is utilised by one person: on a yacht, it is a shared resource that is the basis for conversation and around which actions are formed. It has to inform those actions, and has to change at a rate that allows sensible adjustments to actions and conversations: faster than that renders it less useful – slower than that makes it less reliable. Information therefore has be presented at an actionable rate (Dix, 1992). For position, this may be every second or so: for performance percentages, the frequency is much lower.

8 Conclusions

This study has highlighted a number of issues. A critical one is that, for racing sailors, instruments are not just presentations of the raw or processed data: they act as a focus for conversation and action, and mediate cooperation. We have also found that these displays provide a point of reconnection with the activity after a period of inattention, thereby supporting the fragmented nature of their interactions. In addition, we have found that whilst it is possible to present highly processed data, sailors in general prefer to work with it in a more raw form so that they can immediately see which elements are contributing to a situation and modify their actions accordingly. We have also seen that the data needs to be updated at an appropriate frequency, such that they can respond to it appropriately, and that updating it more often is as counter-productive as not updating it frequently enough so that they are working with out of date information.

We have also seen that effective presentation of information can reduce the cognitive load on participants, and in a motivated team the access to performance data allows them to improve their own levels of excellence and improve. We have also noticed that the role of technology is to provide supporting information, and that good sailors use the data in conjunction with their learned skills in order to achieve excellence. It is not really possible to achieve high levels of results by focussing solely on the numbers, though less expert sailors tend to believe in the infallibility and accuracy of the data and try to sail the boat solely using those.
More generally, there are parallels to be drawn between these systems and others, in particular those in which displays are central, and which inform, even dictate, the actions of individuals and their interactions with others, yet are not interacted with in any direct fashion. The lessons learned here: information as a shared resource, as a language for communication, at an appropriate pace, and as a mechanism for situational awareness, have potential implications for these wider systems.

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10 Appendix
This section describes the manoeuvres and roles played by the crew when sailing, and how they relate to the information presented. It may be of particular use to readers unfamiliar with sailing in general or yacht racing in particular. Even without a full understanding of the terminology, it shows the coordination of actions that are needed to achieve rapid, and safe, manoeuvring of the yacht.

Prestart
The time the sail combinations are decided on and set up – wind speed is the key factor. Cockpit crew pass headsail to mast and bow, who attach it and hoist, with assistance of keyboards. Generally slow manoeuvring; genoa trimmers set sail according to helm or tactician’s instructions - ‘let it flap’ is a common one, so that the boat slows, and the genoa must be released a long way. All keep lookout for other boats as there is no defined direction for boats to be going. Navigator/tactician works out course to first mark, helm works out starting tactics - which end of line, which tack, and so on. Navigator calls out time to the start.

Start
On approach to line, all people in designated positions. Main and genoa trimmers set sail for boat speed as requested by helm – anything from full speed to flapping, and many positions in between: the boat speed numbers are crucial at this stage. Fast response to instructions needed. Tactician keeps eye out for other boats, and works with helm in deciding start line approach. Bow is up on pulpilt, calling distances to line - actual units immaterial as it’s the rate of change of distance that matters, though boatlengths are relatively easy to estimate. Typical X332 starts have us near the line, on starboard, with about 3 mins to go, with slow forward motion and flapping sails, and we accelerate at the last possible moment.

Post-start, we need maximum speed. Helm looks for clear air and aims to get maximum speed, mainsheet trimmer checks set of mainsail and has it in pretty tight, genoa trimmers have hauled in genoa and set it for optimum speed. All use wind speed, sirection and boat speed; if polar numbers are available they provide the benchmarks. All except trimmers move to the windward rail; if main trimmer can work from rail, so much the better.

Close hauled
This is the term given for sailing upwind, which is achieved in a series of zigzags towards the wind. Crew positions should be on rail, unless about to manoeuvre. Positions on the rail are, from the bow backwards: bow, mast, keyboards, genoa trimmers, main trimmer, helm. Sit on the rail facing outboard, body inside at least one lifeline, legs over the side. Tactician is in cabin, or on stern. Genoa trimmer sometimes has to sit to leeward to trim genoa, other times can set it and sit on rail. Default position is genoa in tight. Sail shape can be adjusted with genoa car; back tightens bottom of sail, opens back edge, whilst forwards pulls down back edge and slackens bottom. Default position is sufficient downwards tension to give parallel shape to the mainsail, and is roughly equal foot and leech (back edge) tension. Halyard (rope that hauls sail up) tension also important - tight for better pointing, looser for more power. We rarely adjust this on the beat. Backstay tension should be on high; check with helm that this has been done. Boat speed and true wind angle the key numbers –
true wind direction used to monitor oscillations in the breeze.

Helm steers boat to avoid crashing into waves, but with minimal rudder movements. Mainsheet trimmer adjusts mainsheet, traveller and kicker (though keyboards can actually set kicker if main trimmer can’t reach) to get the best from the main. Light winds see the traveller to windward, mainsheet set so boom along centreline, no kicker. Medium sees traveller in the centre, more mainsheet tension to hold boom down and leech tight, some kicker. Strong winds see lots of mainsheet tension, kicker, and traveller played to keep boat powered up and not broaching to windward. Good communication with helm is important - helm can feel when boat is about to break to windward, and tells trimmer to release the traveller. The earlier and better the communication, the smaller the adjustments need to be. The mainsheet trimmer can help predict the helmsman’s call by watching for gusts and noting how much helm the helmsman is using to keep the boat in a straight line. Generally if the helmsman is pulling the helm as if their life depending upon it and is grunting, chances are they should ask for the main to be eased.

Ideally the mainsheet trimmer should adjust the ‘angle of the attack’ of the mainsail with the traveller and not adjust the mainsheet upwind. We have found on some X332s that this is very hard work unless they have the uprated “race” traveller; you may find that adjusting the mainsheet is the only way to adjust the sail effectively.

Tactician monitors close tactical situation and discusses route to mark with helm, also identifies mark visually and gets next course to steer. All other crew on rail.

**Tacking (turning)**

Helm calls ‘ready to tack’ or similar. Crew move from rail positions to tacking positions: bowman goes towards mast, whoever is winching moves to windward winch, sets up sheet around winch, and wins windward handle from keyboards, who moves to hatchway. Trimmer moves to leeward side in corner of cockpit, facing the windward winch, and takes new sheet; keyboards prepares to release leeward sheet.

Helm calls ‘ready about’. When ready, crew reply ‘ready’. Mainsheet trimmer then eases mainsheet slightly, and if possible sets windward traveller position for after the tack (this is only critical in light winds when the traveller is cleated to windward and needs to be released so it is free to be reset on the new tack). Ideally the main stays powered up until the last possible moment, and then is adjusted during the tack (see later) but this takes practice so is better to be ready early.

Helm calls ‘lee-oh’, and pushes tiller away. Turn is smooth, fairly sharp, and slightly overdone so that boat sails free about 5 degrees immediately after tack to pick up speed. As boom crosses centreline, people need to move across the boat to the new windward side. Bow crosses in front of the mast, and 'skirts' the genoa, lifting it over the lifelines if necessary. Improved manoeuvre is for bow to lie on new windward side in front of shrouds, and grab genoa above their head as it flutters past. Pulling down, they set the front of the genoa, it never crosses the lifelines and so doesn’t need skirting, and means the cockpit have only the back half of the genoa to winch in. Mast crosses over the cabin top, ducking under the boom. Other crew cross cabin roof under boom as well to avoid crowding the cockpit. Keyboards and genoa trimmers are already in cockpit; get there by coming in between genoa and coachroof, or, if further along rail, over coachroof and into leeward side of cockpit.

As boat settles onto new heading main trimmer hardens in main, but this is hard to achieve in practice with the #1 or #2 (large and medium sized genoas). Wincher ensures winch handle back in pocket as returns to rail. Trimmer then adjusts genoa for fine set, using boat speed and wind strength numbers to guide their knowledge, and boat speed to assess success whilst rest of cockpit crew get up onto rail, and then joins them.

As boat settles onto new heading main trimmer hardens in main, pumping air across the sail to accelerate boat out of tack. Traveller position adjusted, and then both helm and trimmer focus on driving the boatspeed back up to the target speeds. Navigator checks tacking angle, local tactics, and runs through new options with helm.

It’s important that once your job is done that you head back to the rail so the boat can sail as fast as possible. This is particularly important in a stronger breeze because we need the weight to keep the boat flat. This takes cunning choreography and practice to get this right.
Supporting cooperative teamwork

**Approaching windward mark (at the 'top' of the course)**

It is here that the crew need to re-engage with the activities, if they have disengaged: knowing when the mark is coming up is therefore useful, so the range and bearing figures are helpful if they are displayed, or good communication from the tactician is needed. Tactician or genoa people pass spinnaker up to keyboards who passes it to mast who passes it to foredeck. Foredeck clips on spinnaker bag at bow, rigs sheets and guys and halyard. Approaching mark on final tack, foredeck rigs pole uphaul and downhaul lines, attaches pole end to guy, attaches pole to mast. Ensure leeward genoa sheet is over the pole.

**Spinnaker hoist**

"There are two places that a spinnaker is under control: in the bag; or hoisted and trimmed. The aim is to get between the two as swiftly as possible"

10.1  **Bear away set**

Helm bears away round mark, main trimmer eases main slightly prior to bear away and continues easing until a run or near run is reached. Cockpit crew take positions for hoist: genoa trimmer becomes spinnaker sheet trimmer, genoa grinder does guy trimming, keyboards will release genoa sheets. Note that the spinnaker trimming roles may be taken by different people. On the command ‘hoist’ given by helm, mast hauls on halyard as fast as possible, and it’s pulled through the jammers by keyboards. Foredeck checks to ensure spinnaker goes up out of bag. As going up, genoa grinder sheets in guy to pull spinnaker to end of pole, and pole back as far as necessary to make it in line with the boom if the boom were extended forwards. Once up mast yells 'done' and spinnaker trimmer sheets in spinnaker. Genoa sheets have to be cleared off winches by keyboards to allow this to happen.

Keyboards then releases genoa halyard; mast and bow haul genoa down to deck - depending on conditions genoa may be tied down or left along deck. If the genoa halyard is released as soon as the spinnaker is up, the genoa will fall part way down the luff groove and allow air into the head of the spinnaker, so do it straight away - you don't need the bow to be ready.

This is the standard set.

10.2  **Gybe set**

Sometimes we need to gybe round the mark and set the spinnaker, so the procedure is different. Bow sets up pole on the leeward side as we approach the mark, with the end of the pole down on the deck in the bow and the inboard end attached to the mast, with the genoa sheets over the pole and in front of the topping lift. Trimmer keeps guy in tight to keep pole at front of boat. As the boat rounds the mark, sheets are eased and the main gybed. As this happens, the genoa is pulled over the pole (ease the sheets a lot to make it simple) and the pole hoisted fast on the uphaul to set it. If the sheet trimmer hoists it, then mast can be hauling the spinnaker halyard hard, along with keyboards, so that the spinnaker appears. Done well, the spinnaker is up and drawing very early. A warning - the guy should be kept in tight until the pole is up, otherwise the pole end slips aft along the deck and under the guard wires, and then can't go up.

For subsequent spinnaker hoists, if the spinnaker is in the forward hatch and not the bag, the same procedure is followed except the spinnaker is hoisted straight from hatch. Bow needs to ensure pole uphaul/downhaul not in way of spinnaker halyards and sheets. This is not easy, and it is worth spending some time in the marina setting this up and seeing what should be under/over what.

**Spinnaker trimming**

Spinnaker is trimmed as follows: pole is roughly in line with boom extension, but back as far as it can without leading edge of spinnaker collapsing, and adjusted vertically so that spinnaker clews are level. To move pole backwards downhaul has to be released by keyboards as guy winched in by grinder. To move pole forwards, guy is eased and downhaul pulled on. Pole must not rest against forestay - guy trimmer's responsibility. Once guy set, spinnaker trimmer eases sheet until luff just curls, then keeps it so that it's on point of collapse. Trimmer and helm communicate to allow helm to react to wind shifts, increases and so on. If the sheet trimmer cannot trim the sail they should request that the guy be adjusted. If the guy trimmer thinks that an adjustment is needed they should run it by the sheet trimmer and helm. The sheet trimmer should sit where they can see the spinnaker luff. There should be enough turns around the winch to give feel and control (no wind – one, to max 3-4 turns). If its breezy the spinnaker trimmer will have a grinder to do the hard work on the winch.

To prevent broach, strong wind in spinnaker reacted to by helm bearing away and spinnaker eased, main eased; if necessary, spinnaker sheet (not the guy) can be let go completely to allow spinnaker to
flap. Helm steers boat under the spinnaker, and mainsheet keeps on hand on the kicker to dump it if necessary.

If the spinnaker goes up twisted, do the following to remove the twist. First, try to set the spinnaker - you're aiming to get the bottom part full so that the air pushes the twist up to the top and the head of the spinnaker can twist free. Pull in both sheet and guy tight, loosen then both, pump them back and forwards, and then pull spinnaker to try and pull twist upwards. If that fails, release halyard a few feet. If all else fails, drop spinnaker onto foredeck, and pull out the twist from the bottom.

The helm steers downwind based on the wind strength, and the polar angles, so needs access to the polar angles, the true wind angle, and true wind strength. This should give optimum speed so that is checked, but is secondary. Trimmers check the true wind angle to guide their actions.

**Spinnaker gybe**

10.3 **End to end**

Helm steer boat onto dead run, calling 'stand by to gybe', mainsheet pulls in mainsheet some. (In more of a breeze the main should be brought closer to the centre line during the gybe, but released swiftly as soon as the main has gybed.) Guy pulled in, spinnaker sheets eased so that spinnaker square on boat. Helm gybes boat, main trimmer pulls boom across, and says 'gybe-oh'. Mast and bow unclip pole from mast, bow clips it onto the old sheet and moves it across boat, mast unclips old guy and aattaches it to mast. When secure, yell 'done'; helm steers onto new course, guy and sheet adjusted as necessary.

Good in light/medium airs, from run or broad reach to same.

10.4 **Dip-pole gybe**

Requires twin sheets and guys on spinnaker, but is better gybe in stronger winds and is our default one. Bow checks lazy sheet is on top of the pole. Lazy guy taken forward by bow, who sits in pulpit facing aft. Cockpit crew need to ensure that lazy guy can run freely else bow gets tugged back a lot. Spinnaker trimmer takes lazy sheet and pulls it tight, taking strain off guy. Helm bears away, mainsheet gybes main. Guy trimmer releases guy - spinnaker trimmer now trims spinnaker on both sheets. Mast trips pole end, releasing guy. If it won't go, as long as guy is loose it's not a problem. Keyboards dumps pole uphaul and pulls on pole downhaul, swinging pole down and forwards to bow. Bow takes out old guy if it's still there, drops new guy in, yells 'done' and keyboards then pulls pole back up on new side. Bow has to ensure that the guy is dropped into the spinnaker jaws the correct way round so that it's not twisted. Once up, guy is tightened and lazy sheet loosened, and spinnaker is trimmed as usual.

It's our standard gybe because it works in any wind, the spinnaker can be kept flying all the way through, and is pretty much under control all the time.

**Spinnaker drop**

10.5 **Leeward drop**

Headsail halyard reattached by bow, clear of pole and uphaul/downhaul. On helm's command of hoist, mast hauls up genoa, assisted by keyboards, who winches final bit home. Mast moves aft to grab sheet, sits under genoa and yells 'ready'. Bow sits next to him, between bow and near forehatch which is now open. Keyboards releases spinnaker halyard and releases it pretty fast, keeping spinnaker out of water, whilst guy trimmer allows guy to run forward. Mast and bow bundle handfuls of spinnaker down and straight down forehatch, which is then closed leaving sheets, guys and halyards attached. Keyboards ensures enough slack in halyard, tensions genoa halyard for beat, whilst genoa trimmer sheets in genoa and helm hardens up for beat. Pole is then removed onto deck, uphaul and downhaul unattached by bow.

Variation is to drop the spinnaker into the cockpit and down the main hatch (where it will need repacking). Guy (and lazy sheet) released fully, and sail bundled down main hatch. This is done with a less experienced crew or when it's windier, or when we don't know which gybe we'll be hoisting the spinnaker on next and so need to pack it.

10.6 **Racing drop**

Genoa up. Sheet pulled in tight, guy held in same position. Keyboards releases halyard completely and lets it run out until head of spinnaker is near water, when halyard is jammed hard. If foot of spinnaker is tight, it floats away from boat, empty of wind, like a flag held horizontal, and the sudden jamming halts its drift towards the sea. Mast and cockpit crew smoke in armfuls from the foot and
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down the main hatch, gathering it fast before it falls into the sea.

Looks spectacular, is a rapid drop, and is supposed to work well in all but light winds - the stronger
the better.

10.7 Floating gybe drop

Used when we need to gybe round a bow and come back on the wind. Genoa up. Pole removed first,
spinnaker trimmed as usual. Boat gybed, then bow takes guy on windward side of boat. On 'ready',
bow pulls spinnaker luff tight with guy and spinnaker sheet let go to collapse spinnaker. Keyboards
releases halyard and mast and bow pull spinnaker down to windward of the genoa, down into hatch.
Once spinnaker coming down, cockpit crew harden boat up onto wind - done well, the genoa acts as a
net to leeward to catch the spinnaker, and it all drops onto the deck and down the hatch. Allows us to
drop spinnaker very late and round the mark effectively.

Once the spinnaker has been dropped it should be repacked straight away.

11 References


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