VOLVO OCEAN RACE INDEPENDENT REPORT INTO OCEAN RACING AT NIGHT IN AREAS OF HIGH VESSEL TRAFFIC DENSITY

The Volvo High Traffic Density Report

Chris Oxenbould, Stan Honey and Chuck Hawley

17 September 2018 Final

Intentionally left blank

Cover photo:

Credit: Jesus Renado/ Volvo Ocean Race

Table of Contents

1. Introduction

Terms of Reference

1. Following the collision between *Vestas 11th Hour Racing* and a non-racing vessel in the final stages of the leg into Hong Kong, the organisers of the Volvo Ocean Race (VOR) commissioned an independent report into ocean racing at night in areas of high vessel traffic density - the Volvo High Traffic Density Report.
2. The report is not required to investigate the collision incident but is intended to draw on the experiences from recent editions of the VOR to establish what steps race organisers may consider to mitigate risk in areas of high traffic density in the future. Terms of Reference were finalised and issued on 23 February 2018. A copy is at Appendix 1.

Independent Report Team

3. VOR invited Rear Admiral Chris Oxenbould AO RAN (Rtd), Stan Honey and Chuck Hawley to form an independent report team with Chris as the chair. Brief resumes of the three team members are at Appendix 2. The team is to make findings and recommendations that might improve safety and any other matters relating to the conduct of the race that the team considers appropriate.
4. The chair travelled to Hong Kong late in January to discuss with Richard Brisius, the VOR President, the opportunity to conduct a report and hold some preliminary meetings.
5. The three team members travelled to New Zealand in March and interviewed the skippers and navigators of all racing teams in the current edition of the race during the Auckland stopover. The Race Director, some other crew members and staff involved in the management of the race plus other people with relevant experience and expertise were also interviewed at this time. Any subsequent queries have been resolved through phone calls and email exchanges.
6. The report team met with or interviewed a total of 35 people and a further 9 people were contacted by email and/or phone. A list of those with whom the the team communicated is at Appendix 3.
7. This report is structured to provide general information at Sections 1-4 followed by the facts and information obtained from the crews at Section 5. This information is analysed by the report team at Section 6 and leads to the recommendations at Section 7. The recommendations commence at paragraph 286 on page 52.

2. The Race

8. The Volvo Ocean Race is one of sailing's pinnacle offshore races: a crewed race round the world and a demanding test of a team in professional sport. The race is gruelling and justifiably marketed as 'Life at the Extreme'. More than 2,000 sailors have taken part in 12 previous editions dating back to 1973, when the race began life as the Whitbread Round the World Race.
9. The 2017-18 edition started from Alicante, Spain on 22 October 2017 and finished in The Hague, Netherlands on 24 June 2018. The race course included 11 legs over

45,000 nautical miles – or more than 83,000 kilometres and stops in 12 major cities on six continents.

3. The Boats

10. The boats used in the 2017-18 edition of the race are Volvo Ocean 65 (VO 65) class, first built for and raced in 2014-15 edition of the VOR. The boats are built to a single, tightly controlled set of plans from Farr Yacht Design and administered through a strict closed class rule with extremely tight tolerances.
11. The introduction of the VO 65 created a level playing field and close racing. In the 2014-15 edition six out of the seven teams won a leg of the race and an In-Port race. The class has been generally well received by the teams and race followers with only a few minor criticisms.
12. The positives are the one-design concept and strength, though the boat is not unbreakable as demonstrated in the Southern Ocean during the rugged legs 3 and 7 of this edition. The perceived deficiencies are that the boat is relatively heavy, under-powered and slow for a modern ocean racer of its length. As with many modern racing yachts with large overlapping headsails, it is also difficult for a crew to maintain a proper visual look-out.
13. On balance the boat continues to provide excellent close racing and the robustness has taken 'some of the stress' out of sailing a boat hard. More details of the VO 65 are available on the website https://www.volvooceanrace.com/en/boat.html.

4. The Rules

14. The VOR sets its own regulations for the race and has a very strict requirement to comply. These are promulgated through the:
    - Racing Rules of Sailing 2017-2020,
    - Equipment Rules of Sailing 2017-2020,
    - Notice of Race,
    - Sailing Instructions and their Addenda,
    - VO 65 Class Rules 2017,
    - VO 65 Class Specification, and
    - The Commercial Partnership Agreement.

13\. These documents provide a framework that stipulates the requisites for crew member certification and qualifications to race. The certification is comprehensive and requires:
    - at least two crew to have as a minimum a Royal Yachting Association (RYA)/ Maritime and Coastguard Agency (MCA) Yachtmaster Ocean qualification or equivalent,
    - all other crew to have as a minimum a RYA/MCA Yachtmaster Coastal Skipper (now titled Yachtmaster Coastal) qualification or equivalent,
    - at least two crew members to have specified medical qualifications,

- at least two crew members to hold a General Operator's Certificate, Global Maritime Distress and Safety System (GMDSS),
- all crew members to undergo a medical and dental examination, and
- all crew members to have a nationally recognised first aid certificate.

14. In addition the Notice of Race lists mandated briefings and crew training that includes a three day safety course, requirements for emergency drills and procedures plus some technical courses.
15. VOR does not reference World Sailing's Offshore Special Regulations (OSRs) and the requirements of Category 0[1]. VOR considers that its race requirements are more stringent and indeed Cat 0 was derived from the requirements used by the VOR in previous races.
16. VOR has a race control centre at Alicante that keeps a very close monitor on competing boats and gathers a great deal of telemetry data. Race Control does establish exclusion zones to route the fleet clear of the Antarctic ice, tropical storms and other dangers when considered necessary.
17. The boats are provided to teams fully equipped to the rules and are maintained through an efficient common Boatyard servicing system. Considerable onus is, however, placed on teams and sailors to plan and operate within this strict regime using their own resources. These vary between teams depending on the available budget. Some have backup navigational, meteorological, routing and other technical support available prior to each leg, while others do not.
18. The Racing Rules of Sailing (RRS) invoke the International Regulations for Preventing Collisions at Sea (IRPCAS), when a boat sailing under the racing rules meets a vessel that is not doing so. This is the most likely situation in the areas of vessel traffic considered in this report and the international regulations are relevant in virtually all circumstances.

International Regulations

19. IRPCAS are based on rules initially drafted over 50 years ago and have been subject to little change. Most of the rules have stood the test of time well, though there are some areas regarding the positioning and technical details of lights that should be updated. Generally the regulations are carefully worded to provide the mariner firm guidance with some practical flexibility. They are less prescriptive than the RRS which include the requirement to rapidly assess who is in the right or wrong in order to facilitate fair competition.
20. IRPCAS stipulate many requirements for preventing collisions. Two of the most fundamental rules apply at all times and are very pertinent to this report and worthy of elaboration to avoid any confusion. They relate to maintaining a 'Look-out' and proceeding at a 'Safe Speed'.
21. Also included in IRPCAS are the requirements and specifications for navigation lights. Their important role is to signal a vessel's presence at night, or in restricted

[1] **Cat 0** - Trans-oceanic races, including races which pass through areas in which air or sea temperatures are likely to be less than 5°C (41°F) other than temporarily, where boats must be completely self-sufficient for very extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without the expectation of outside assistance

visibility, and an indication of the vessels aspect or angle of approach. The lights should also identify the type of vessel and at times any specific activity or circumstance that need to be considered by other mariners.

22. While the rules might not have changed much over the 50 years, offshore ocean racing yachts certainly have: they are bigger and faster. The design of a modern offshore racer and its sail plan make it difficult to comply with the existing regulations for lights. Also it is arguable whether the lights continue to fulfil their intended purpose.

Look-out

23. Rule 5 states:

> "Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision."

24. Importantly, the rule refers to a 'proper look-out' and 'all means appropriate in the prevailing circumstances'. The rule does not require a continuous 360° visual lookout as this would be impractical in almost every circumstance on nearly any vessel. Sight and hearing are specifically mentioned in the regulations but the lookout is to be enhanced by 'all means appropriate' which includes radar, Automatic Identification System (AIS) and a Very High Frequency (VHF) radio watch.

25. Normally at sea the 'prevailing circumstances' will be changing frequently and will impact the level of look-out able to be maintained. The level of look-out will improve or deteriorate depending upon the circumstances - day or night, fog, heavy rain, single handed of fully crewed etc.

26. The person in charge[2](PIC) of a boat is required to make a judgement on what is a 'proper look-out' for the prevailing circumstances and make it as effective as possible. In a VO 65 the visual look-out is aided by radar and AIS which are discussed in more detail in Sections 5 and 6 of this report.

Safe Speed

27. Rule 6 states:

> "Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.
>
> In determining a safe speed the following factors shall be among those taken into account:
>
> (a) By all vessels:
>
> (i) the state of visibility;
> (ii) the traffic density including concentrations of fishing vessels or any other vessels;
> (iii) the manoeuvrability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions;

[2] Person in Charge (PIC). A technical term defined in the Sailing Instructions with the onerous sole and inescapable responsibility for the safety of the boat and all persons onboard. A PIC (sea) and a Reserve PIC (sea) are required to be nominated and sign declarations. The PIC is colloquially known as the 'Skipper'.

(iv) at night the presence of background light such as from shore lights or from the back scatter of her own lights;

(v) the state of wind, sea and current, and the proximity of navigational hazards;

(vi) the draught in relation to the available depth of water.

(b) Additionally by vessels with operational radar

(i) the characteristics, efficiency and limitations of the radar equipment;

(ii) any constraints imposed by the radar range scale in use;

(iii) the effects on radar detection of the sea state, weather and other sources of interference;

(iv) the possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;

(v) the number, location and movement of vessels detected by radar;

(vi) the more exact assessment of the visibility that may be possible when radar is used to determine the range of vessels and other objects in the vicinity."

28. The rule is very clear: "Every vessel shall at all times proceed at a safe speed …". There is no option, but there is a list of factors to be considered that will be frequently changing.

29. Again the PIC of a boat is required to make a judgement as to what is a safe speed for the prevailing circumstances and conditions and should not exceed that speed.

Navigation Lights

30. The navigation light requirements for a sailing vessel are quite simple: a red sidelight on the port bow, a green sidelight on the starboard bow and a sternlight showing a white light over the arc astern not covered by the sidelights.

31. On a VO 65 these navigation lights are fitted at the masthead in a combined fitting that houses the three separate lights, about 30m above the water. In a vessel less than 50m in length the sidelights and sternlight are required to have a minimum range of 2nm but this is generally exceeded with light emitting diodes (LEDs), currently used.

32. These single lights provide short warning of a boat's presence, especially if travelling at high speed, and make it difficult to judge the boat's aspect and range. Presuming the lights just meet the 2nm requirement, and the vessel is sailing at 20 knots, they might only be visible for as little as six minutes or less before a close quarters situation. This will be discussed further in Section 6.

5. Deduced Facts

What is a HVTD

33. The term high vessel traffic density (HVTD) area used in the Terms of Reference is not precisely defined. However most who have spent time at sea around the world have encountered such areas and have a good understanding of what is meant. For the purposes of this report the team has defined a HVTD as:

> A relatively small navigable area with a high number of vessels clustered together, usually fishing vessels, such that the density of vessels requires others

transiting the area to frequently alter course and/or speed to avoid a risk of collision and requires passing some vessels at a close distance.[3]

34. There are many such areas around the world. Some are static and some move with the fish. The risks within the area can be compounded in the vicinity of busy international shipping routes or areas of active commercial coastal trade. The situation can be made even more challenging if the fishing vessels and other craft are small, difficult to see and have a weak radar return or are unlit or only display lights when approached by another vessel. Some vessels are likely not to have an active AIS transponder.

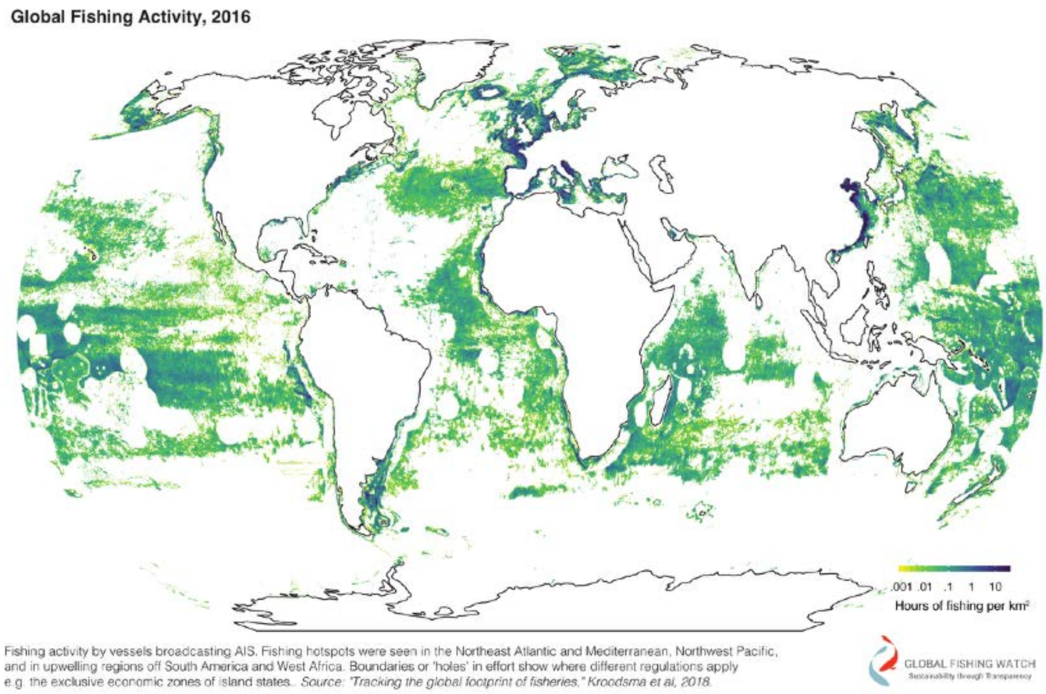

Figure 1 - Global Fishing Activity 2016 - depicting fishing activity around the world and the high density of activity on the Chinese coast

35. All crews were familiar with high vessel traffic areas, and had come across these congested areas in different parts of the world: the Strait of Malacca, Singapore Strait, Strait of Dover and off the coasts of Vietnam, China, Japan, Taiwan, India the north west of Spain, Brittany, around Britain and Brazil. Indeed many parts of the world.

36. The different areas were noted as having their own unique characteristics and that some areas were more challenging than the approaches to Hong Kong. In some of the areas obstructions, such as nets, stretching as far as 5 nautical miles (nm), and fish traps were equally as hazardous as the fishing boats. HVTDs present a heightened risk of collision and owing to the varying characteristics, local knowledge of the the specifics of the fleet and resultant risks are important.

[3] There are other types of HVTD areas such as Traffic Separation Schemes (TSS) in focal areas of international commercial shipping such as the Straits of Gibraltar or Dover or Malacca

Hong Kong

37. The risks involved while approaching Hong Kong Harbour attracts a general comment in sailing directions. The British Admiralty Pilot[4] notes fishing as a major industry in many countries bordering the South China Sea and that 'progressive modernisation has extended the fishing grounds'. Trawling is identified as a 'significant development in these open-sea operations. … within the 100 metre (m) depth contour…'. Off Hong Kong, 'trawling and long-line fishing operations are noted to continue for most of the year'.

38. The Pilot states there are 'about 10,000 vessels engaged in fishing at Hong Kong and while many undertake only limited day to day inshore operations, a great percentage do operate in the offshore regions.' 'Sizeable fleets of fishing junks may be met off the coast of China …. Chinese junks may not carry the regulation lights.' The US Enroute Sailing Directions for the South China Sea refers to these fleets as 'enormous' off the coast of China and has the same warning about their lights.

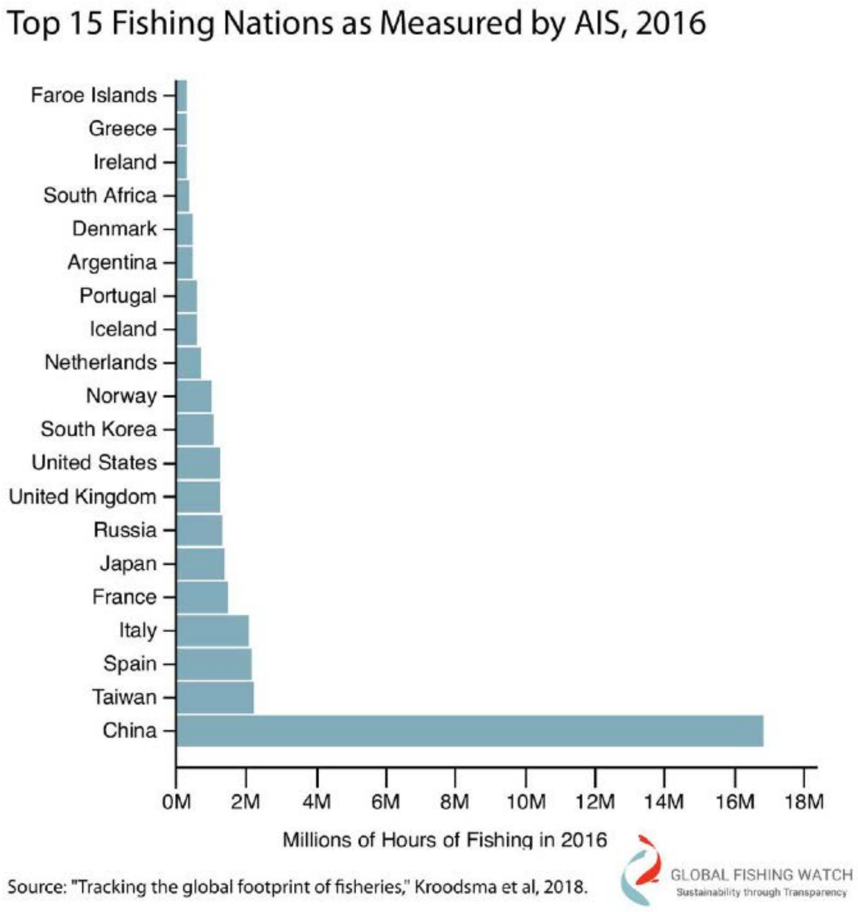

Figure 2 - Top 15 Fishing Nations depicting the predominance of Chinese fishers

[4] The UK Hydrographic Office version of Sailing Directions with 74 volumes providing world-wide coverage of guidance for general navigation and passage planning.

39. All teams had experienced the high density of vessels when approaching Hong Kong and this was used as a benchmark to obtain their experiences and how they dealt with the risk. From the interviews with crews, a clear picture was painted of these congested waters. Spatially, the fishing boats are concentrated in a relatively narrow band, about 5-20nm wide, situated on the continental shelf within the 100m depth contour line. This band would normally start 5-20nm off the coast but at times the outer limit could be as far as 100nm off the coast.

40. The congested area off Hong Kong is traversed by shipping lanes entering and leaving the port and there is an active coastal trade of small to medium sized commercial vessels. Hong Kong is currently ranked as about the fifth busiest trading port in the world with a daily average of arrivals of about 75 ocean-going ships and 430 river trade vessels.

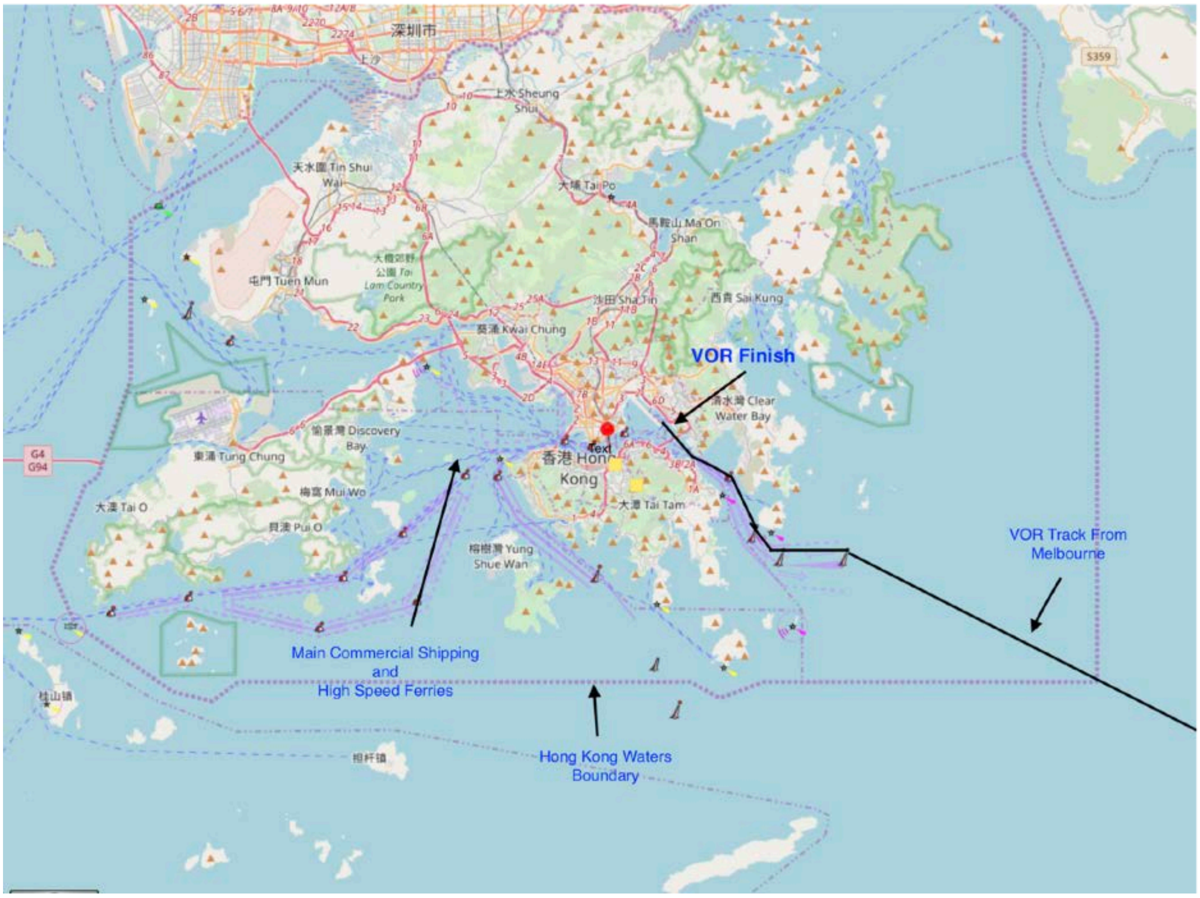

Figure 3 - Approaches to Hong Kong - major shipping routes and ferry traffic to the west of Hong Kong Island - the Volvo Fleet approached from the East

41. A major north-south shipping route from northern Chinese ports, Korea and Japan to the Singapore Strait - leading to India, the Middle East, Africa and Europe - passes to the east of Taiwan and through the Luzon Strait closer to the Philippines. It is well clear of the Hong Kong fishing fleet. Closer inshore there is an active ferry network which includes very fast jet-foils operating at speeds up to 40-50 knots. However this network is to the west of Hong Kong and is clear of the Volvo route from

Melbourne which approached Victoria Harbour from the east.

42. Crews reported increasing fishing activity after passing through the Luzon Strait, north of the Philippines, about 400nm from Hong Kong, before reaching the more concentrated band as they closed the Chinese coast.

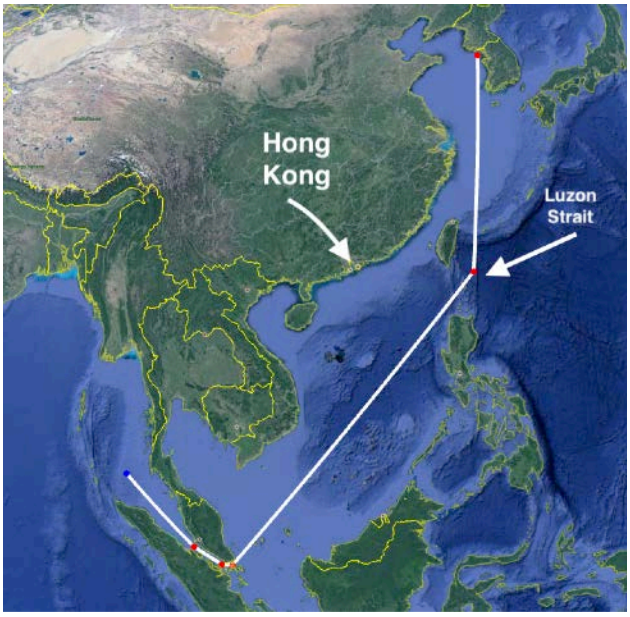

Figure 4 - Major north - south shipping route from North Asia to the Singapore Strait - clear of Hong

AIS

43. In the Hong Kong approaches a very high percentage of fishing boats had AIS transponders. Crews estimated that between 75-100% of the fishing vessels were equipped with AIS. There were no reported incidents of a sighted vessel that did not have AIS but one crew did report vessels working in pairs where only one had AIS. Some fishing nets were marked at the ends with AIS.

44. There was some speculation that there was more likelihood of vessels being unlit and not fitted with AIS closer to the shore. Generally it was acknowledged that the number of vessels with AIS varied depending on the local regulatory authorities. One observation was made that near major coastal cities all vessels and floating nets were more likely to have AIS.

45. Some crews reported AIS contacts at close distance but could not see a boat to correlate with the contact. They may have been nets or small maker buoys.

Lights

46. Most boats passed through the dense traffic area at night and in dark, clear conditions with no moon. They reported the lights of fishing boats all around the horizon. The mass of lights is a noted feature of these congested areas. While providing a daunting situation it was noted as being easier than approaching a coast, such as Miami, with many background lights absorbing the lights of nearby vessels against the shore.

47. No crews reported sighting a single unlit boat while approaching Hong Kong. However, most teams reported unlit vessels, and some near misses, at other times in their sailing careers. Some stated it was a big problem 10-15 years ago but less common now. Again this depended on location; the coast of Vietnam was renowned by crews for unlit vessels in the previous edition of the race but the proportion fitted with AIS was good.

48. While virtually all of the fishing vessels were lit, few if any of the lights complied with IRPCAS requirements for vessels engaged in fishing or trawling or even as a power driven vessel underway. Many had quite bright lights either to attract fish or as deck working lights and these may have hidden any distinctive characteristic of other lights that might have been displayed.

49. Some fishing boats used lights to shine on gear in the water and towards approaching vessels to warn them of the danger. Some fishing gear was marked with LEDs but it was hard to estimate the range as it is difficult to determine how far away LED lights are from the observer.

50. There were some comments about small tenders working close to mother vessels being unlit. Despite the lack of lights these small vessels were also reported as being likely to have AIS as it was used as a location device by the mother ship to recover the tenders. It could be that when observed the lights of the tender were blanked out or obscured by the bright lights of the mother vessel.

51. One crew with considerable experience in the area assessed the probability of encountering a boat without AIS and lights as very low in Asia with the possible exception of some mainland Chinese waterways. This crew also commented that the fishermen were trying to protect their gear and make a living, they are generally good seamen, were not reckless and had a natural interest in their own and other vessel safety. These comments were corroborated by the high usage of active AIS and some form of lighting.

Auckland

52. Apart from the Hong Kong experience all crews cited the finish in Auckland as a challenging congested area. The boats arrived at night, there were a high number of spectator craft, the channel was relatively confined with strong wind conditions and limited room to manoeuvre after finishing - not enough ‘runway’ was a frequently made comment.

53. The wind was gusting up to 26 knots and the boats were running before it, at times at speeds of 25 knots. Press boats were using bright lights that were shone at the crews and impacting their night vision. Some of the small boats were unlit but generally all were well handled. The lights that were displayed on spectator craft made it difficult to pick out the navigation markers and the finishing line.

54. The spectator fleet was difficult to control without predetermined and clearly marked restricted areas. Spectators approached very close to the VOR boats who were required to gybe in these conditions. At least two of the VOR fleet reported broaching and almost colliding with some spectators.

55. Once the boats finished there was little room to furl the sails. This situation was aggravated by the close finish and a number of boats trying to use the small area available at the same time and making their way to the dock.

Crew Inputs

56. All the crew members interviewed were very cooperative and provided helpful contributions. The report team is extremely grateful for their assistance and the time that they provided from their very busy and full schedules. A summary of their inputs follow:

The Risk

57. When asked about the risks associated with sailing in high traffic density areas the responses varied over a wide spectrum. One crew suggested that the commercial pressures were now forcing the fleet to sail in ‘unsafe’ waters. This was a single perspective. At the other end of the spectrum crews suggested that the approach to

Hong Kong was 'stressful but a routine hazard associated with ocean racing and was manageable'. The point was made by several crews that they are professional sailors and the VOR is a different event to the Clipper Race.

58. The congested waters they had experienced in other parts of the world varied from being highly organised such as the Straits of Dover, Singapore and Malacca to unregulated coastal areas where fishing vessels may not be lit and may not have an active AIS transponder.

59. All crews were expecting some degree of fishing vessel congestion off Hong Kong. This was based on normal passage preparation, sailing directions, personal experience or advice from former colleagues who live in Hong Kong. There was quite a variation in the depth of knowledge of the fishing techniques and likely behaviour of the fishing vessels that were encountered.

60. While there were a great number of vessels in the area, they did not form an impenetrable barrier. There was not a requirement to be continually altering course or carrying out a form of slalom through the fishing fleet. The fishing vessels were either stationary or travelling at slow speeds of 3-6 knots. Large course alterations were not required. Course changes of 5°-10° were usually sufficient to avoid contacts and were not required all that often. The boats however are very sensitive to optimum sailing angles and even a few degrees of course change can reduce speed by a few knots.

61. A general summation of the risk was that it was a stressful and tiring period requiring considerable care while going through the main concentration of fishing boats - 'a problem but wouldn't stop you going there'. On average, crews reported only having to change course about three times as they passed through the fishing fleet.

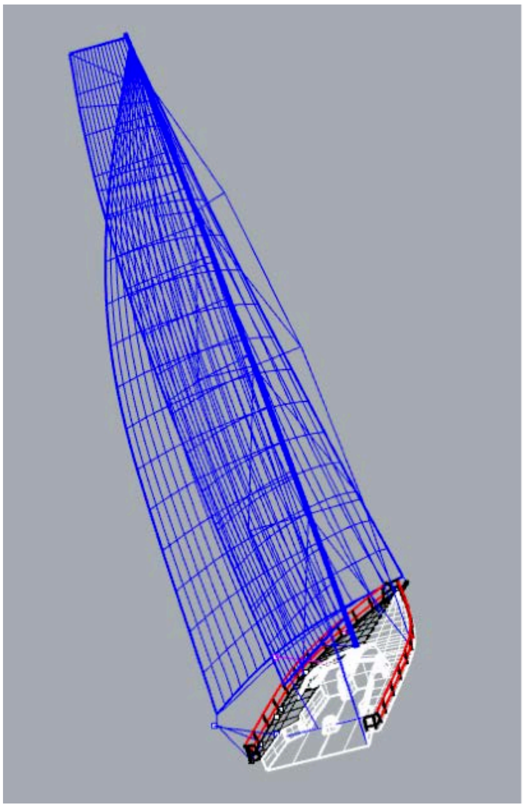

Figure 5 - A rendering of the sail *plan of a VO 65 - with a full main and a MHO sheeted through the aft outrigger*

Maintaining a Look-out

62. All crews were acutely aware of the problem created by the sail plan and the ability to maintain a good lookout on the lee bow[5]. Depending upon which headsails were set there could be an arc of about 90° from the helmsman's position that would be blanked out - from a few degrees on the lee bow to abeam on the lee side. The crews applied themselves diligently to overcome the problem.

63. The A3 Gennaker (A3) and Masthead Code 0 (MH0) cause the most difficulty when running or reaching; being set from the end of the bowsprit, with a low foot and

[5] lee bow: the opposite bow to the windward side. The side on which the sails are set and obscure the look-out.

sheeted well aft nearly adjacent to the helmsman. The use of an outrigger[6] to sheet the sails further outboard can increase the forward looking blind arc. The situation is further aggravated for a large portion of the time racing, when the boat is being pressed hard on a reach and sailing on a large angle of heel at about 30°; the boom and mainsail can also restrict the line of sight to leeward.

Figure 6 - The VO 65 headsail sail plan

64. The A3 is not used very often offshore but a double or triple headsail rig with the MHO is a popular sail option. The Fractional Rig Code 0 (FRO) has a higher foot and a

Figure 7 - Sun Hung Kai/Scallywag sailing with a triple headsail rig - MHO, J2 and J3 - the MHO is sheeted through a outrigger
Credit: Konrad Frost / Volvo Ocean Race

[6]Outrigger: Short spars 2.6m in length that can be fitted at the sheeting position for the J sails (abeam the mast) and the Code 0s and A3 sails (abeam the helm) to allow the sails to be sheeted outboard from the hull

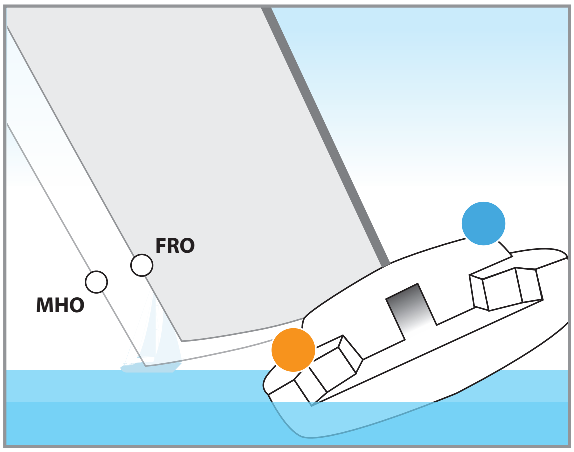

Figure 8 -Depiction of the look-out from the cockpit - Blue dot the Helmsman - Orange dot the leeward lookout - Different arcs of visibility with MHO and FRO

65. Crews developed techniques that varied slightly between boats. The helmsman has the best view, positioned high on the windward side and looking ahead with a clear view to windward and the ability to see past the headsail's luff for a few degrees on the lee bow. Other crew on deck can watch to leeward and astern.

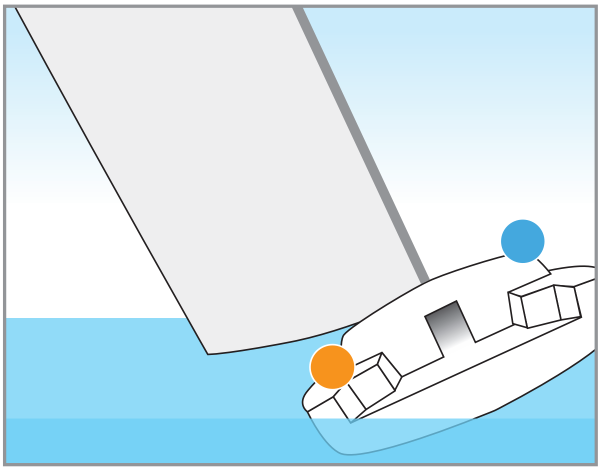

Figure 10 - Look-out from a trough between waves

shorter overlap providing an improved lookout underneath the sail; estimated as a 20% improvement on the MHO or A3. Some boats opt for a FRO and sail a tighter true wind angle (TWA) in situations where the look-out is important; such as the approaches to Hong Kong. As the headsails reduce in size, the look-out improves. While sailing to windward an all-round look-out is relatively easy.

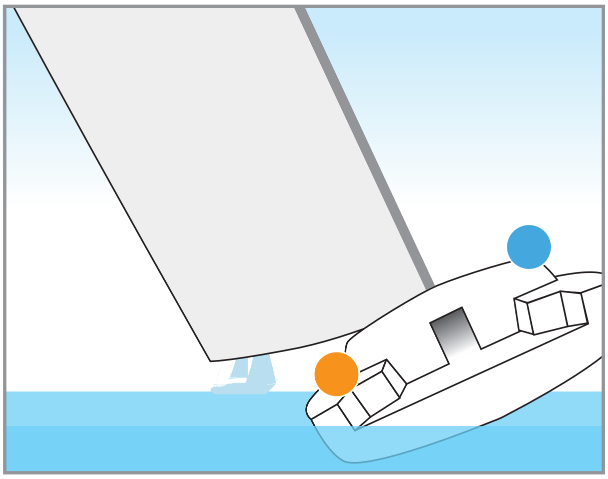

Figure 9 - Look-out from the crest of a wave

66. In many circumstances the grinder or trimmer can go down to leeward and take a look under the headsail but this does depend on the conditions and takes the crew member away from the prime task. The look-out could have to wait to leeward for up to 30 seconds until the boat was on the crest of a wave and gain a glimpse, lasting for a few seconds, out to the horizon. If the boat is sailing fast there is a lot of green water and spray and this is more difficult - 'the look-out needs a mask and snorkel'.

67. In some circumstances a dedicated look-out is required. Two crews preferred to place a look-out as far aft as possible in the lee corner, to look around the back of the sail or possibly underneath the sail. This is made more difficult if an outrigger is being used for the Code 0s or A3.

68. The arcs of view of the helmsman and look-out down aft can leave a gap of about 20°-30° that remains obscured by the sails. Boats look-out in this gap by ‘dipping the bow’ - a quick alteration of course of up to 30° to leeward every few minutes to provide the helmsman a glimpse in that arc. For an effective lookout the time interval would depend upon the visibility, speed of the boat, traffic density and the look-out arcs available with the sails set. All crews reported using the ‘dip’ technique at times but to differing degrees.

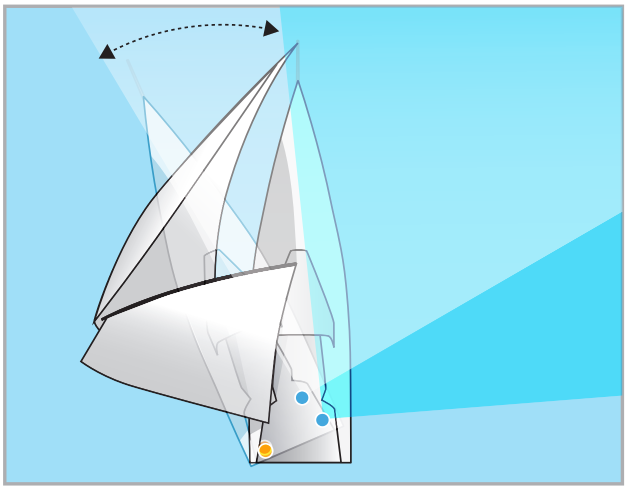

Figure 11 - ‘Dipping’ the bow to leeward by 20° demonstrating the the increased look-out to leeward available to the helmsman

69. The depictions at Figures 8-11 are simple two dimensional presentation of a far more fluid situation with a multitude of variables and a third dimension. They are provided to give a perception of the problem. The judgements regarding the technique, location and frequency of the lookout have to be assessed against the actuals, including the set of the sails, the visibility, the sea state, the boat’s movement, the angle of heel and what can be achieved.

70. The report team was provided with the telemetry data for each boat for the four hours prior to their arrival at Hong Kong. This covered the fleet passing through the area of congested fishing activity. In the approach to the entrance channel, the sailing conditions were relatively consistent over the period of about 11 hours that the fleet took to pass through the area.

71. The approach heading to the channel was about 290° to 300°, the wind speed was between 20-25 knots from a true direction of 065° veering to 080°, providing a TWA of 120°-140° and the boats were sailing on an angle of heel between 10°-30°.

72. Most boats oscillated within 5° of their base course. One boat took a few dips of 15° to 20° and another took frequent dips of 15°-20° every 5 to 12 minutes and the occasional dip to near 30°. For much of the time boats were sailing deep with a modest angle of heel of 10 °- 20°. The boats had different sail arrangements which would have allowed different levels of visual look-out.

73. A good level of communication was required between the helmsman, the navigation station with AIS and any lookouts that might be posted. Radar was of little help. There were a lot of lights all around the horizon. All vessels were assumed to be engaged in fishing and had to be avoided.

74. There was criticism from at least two skippers that the less experienced crew were relying too much on AIS and not looking at the lights to gain good awareness of the situation. Some boats had night vision equipment but it was of no use looking under sails. Infrared (IR) and light intensifying equipment was degraded by the IR floodlight in the cockpit as part of the installed camera system and were unable to be used unless carefully shielded from the IR floodlight.

75. In seeking ideas to improve the lookout, some thought that clear panels in the sails would be worth investigating or at least not painting[7] a triangular section in the foot of the headsails, which might allow some light from a vessel to leeward to be detected.

76. In summary, there was some variation in the methods applied to maintain a 'proper' visual lookout and overcome the blind arc problems created by the sail plan. With sufficient application most crews were comfortable that an adequate visual look-out is difficult but achievable.

The Need to be Seen

77. To practise good seamanship vessels not only need to maintain a 'proper look-out' but just as importantly they need to 'be seen' so that appropriate and timely actions can be taken to avoid collisions.

78. Crews reported that on occasions they have startled vessels as they approached and passed them without warning. Some comments were 'lights at the masthead are ineffective at close range', 'fishermen don't look up', 'other boats can't see us', 'once in a while used deck lights to enhance our visibility' and 'we have surprised boats lots of times'. The situation is worse on a moonless night when dark sails blend into the blackness.

79. In certain circumstances at night the visibility of a VO 65 is insufficient and needs to be enhanced as an anti-collision measure.

Safe Speed

80. All boats were very aware of the requirement to proceed at a 'safe speed' and conscious of the conflict that emerges for a racing yacht. Clearly all crews are very competitive and trying to sail their boats as fast as possible. When the fleet is close together the competitiveness is even keener and boats are willing to push the boundaries and take extra risks to gain an advantage.

81. As the boats approached Hong Kong and passed through the congested waters they were spread out. At the time of the collision *Scallywag* was about to finish and was 30nm ahead of *Vestas 11th Hour Racing*. *Dongfeng Race Team* was 15nm astern. There was then a 60nm gap to *AkzoNobel and* a further 60nm to *MAPFRE*. They were followed by *Team Brunel,* 36nm behind and *Turn the Tide on Plastic* another 10nm further back. With only a few miles to sail, there were virtually no passing opportunities remaining. Although ever-present, the competitive pressures and willingness to accept risk were not at a peak.

82. In general, the discussion regarding safe speed was a little confused and parts of IRPCAS misinterpreted.The crews' recall of IRPCAS Rule 6 was not precise. There was not a clear understanding of the important qualifier specifying the purpose of the

[7] Currently all of the sails, except the A3, are painted to provide a base for sponsor's logos and signage.

rule: a ‘safe speed so that she can take proper and effective action to avoid collision…’ A VO 65 with a watch on deck can change course quickly. For example, when reaching or running, the boat can bear off quickly.

83. Nevertheless, crews reported a relatively conservative approach while among the fishing boats approaching Hong Kong. Some crews sailing ‘off speed’, possibly by a few knots, for up to 30% of the time, noting that this may only be a few degrees off the desired heading. Another crew made the point ‘we can accommodate high speed: AIS, radar, eyes’, but qualified the statement by saying they were ‘more concerned with avoiding collision than reducing distance to the finish’.

84. All boats practised ‘dipping’ the bow, to some degree, to gain a lookout on the lee bow and accepted the momentary loss of speed. One boat was less committed to dipping but used a FR0 to gain a better lookout to leeward at a critical part of the transit and may have incurred a slight reduction in speed.

85. Some crews were asked what they would do in fog in a congested waterway and they acknowledged that they would probably reduce speed depending upon the other circumstances and conditions.

86. Overall it appears that the boats do sacrifice speed to avoid collisions and as expected try and keep any reduction to the minimum. The quality of the look-out will have an important impact on the assessment of a ‘safe speed’. This is discussed further at Section 6.

AIS

87. The AIS system fitted to the VO 65 is a Navico 400 Class B built by SRT Marine Systems with a SRT antenna splitter using an 18 inch (quarter wave) masthead VHF antenna that is mounted on a BNC coaxial connector. The equipment provides a look-out aid with an unrestricted 360° field of reception. Potentially, it is the preferred fitted aid to back up the visual look-out.

88. Unless a contact has very bright lights, the initial detection is likely to be made on AIS and needs to be correlated with a visual contact to confirm the data and risk of collision assessment. The AIS data can be displayed on the laptop displays, using Expedition or Adrena systems, and and the MFDs located at the navigation station (9 inch display) or at the 'tunnel' (7 inch display). The latter can be viewed by some of the crew on deck.

89. The performance of AIS in some boats has, however, been degraded with a marked difference in detection ranges and strength of signal. A monitor of the VOR fleet approaching Hong Kong on MarineTraffic.com picked up most boats between 3-10nm from the finish. Four of the six boats with serviceable AIS were detected at less than 4nm. The range difference might have been due to a degraded signal from the boats.

90. Crews reported range variations of detecting contacts from normally 7-11nm down to as little as 2nm for some other VOR boats. One boat had no AIS available as it approached Hong Kong and had to negotiate the congested area without this important aid. Media reports from boats on leg 7 indicated that two boats had no AIS a few days after departing from Auckland.

91. From discussions with the Boatyard staff, the problem would appear to be with water contaminating the foam dielectric used in the coaxial cable and its absorption of water. *MAPFRE* was one of the boats reported with a degraded signal and had the

cable replaced in Auckland. The problem was fixed as a result. The water appears to be entering the coaxial cable at the BNC connector used at the base of the antenna at the masthead.

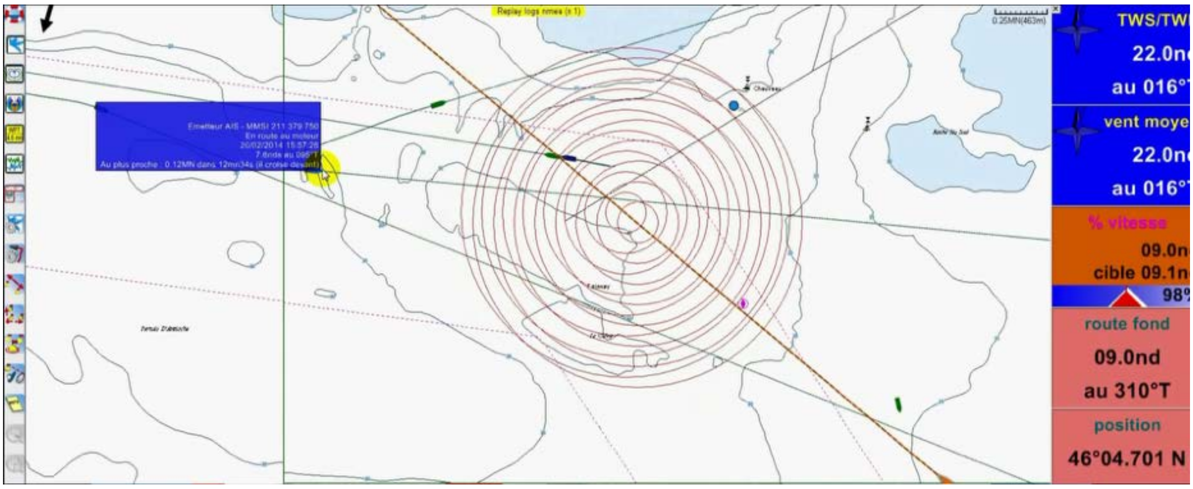

Figure 12 - Adrena presentation - the Blue text box (top left) includes - At the nearest 0.12nm in 12 min 34 sec (he crosses ahead) - the CPA information

92. When interviewing the crews, the Adrena AIS interface was reported as easier to use than Expedition. Adrena's AIS display specifies whether the closest point of approach (CPA) has the other vessel passing ahead or astern of your own vessel. This provides a simple interpretation of which way to turn to increase the CPA. Adrena's AIS display was reported to become complicated and difficult to use in dense traffic environments.

93. Figure 12 is from Adrena. The test boat is in the lower right on a north westerly heading (310°). The user has placed the cursor over an AIS contact which is then highlighted with the yellow dot. The circles show the location of the possible collision and tend to complicate the display without adding much information. The blue text box appears when the cursor is placed over an AIS contact and is informative. The data provided is the Maritime Mobile Service Identity (MMSI), the description 'underway under power', the course and speed over the ground and information about the CPA.

94. Expedition's display is considered better in dense environments by some crews. In Figure 13 the test vessel is the green vessel in the middle of the screen heading north and the contact of interest is the *Louis P* to the north east of the test vessel, exiting the strait. The predictor line length or speed leader is set to 10 minutes. These navigation systems are evolving in response to user feedback. The most recent Expedition version provides three different means of obtaining CPA information.

95. The first involves interpreting the speed leaders from the test vessel and a contact. By observing the intersection of the test vessel's track and that of the *Louis P,* we can observe that it is about 60% along the *Louis P*'s predictor line and the 60% point on the test vessel predictor line is well beyond the intersection point. This means the *Louis P* will pass astern. This is a popular means of working out a CPA but is not a precise measurement and prone to error if the operator is tired and faced with a congested screen.

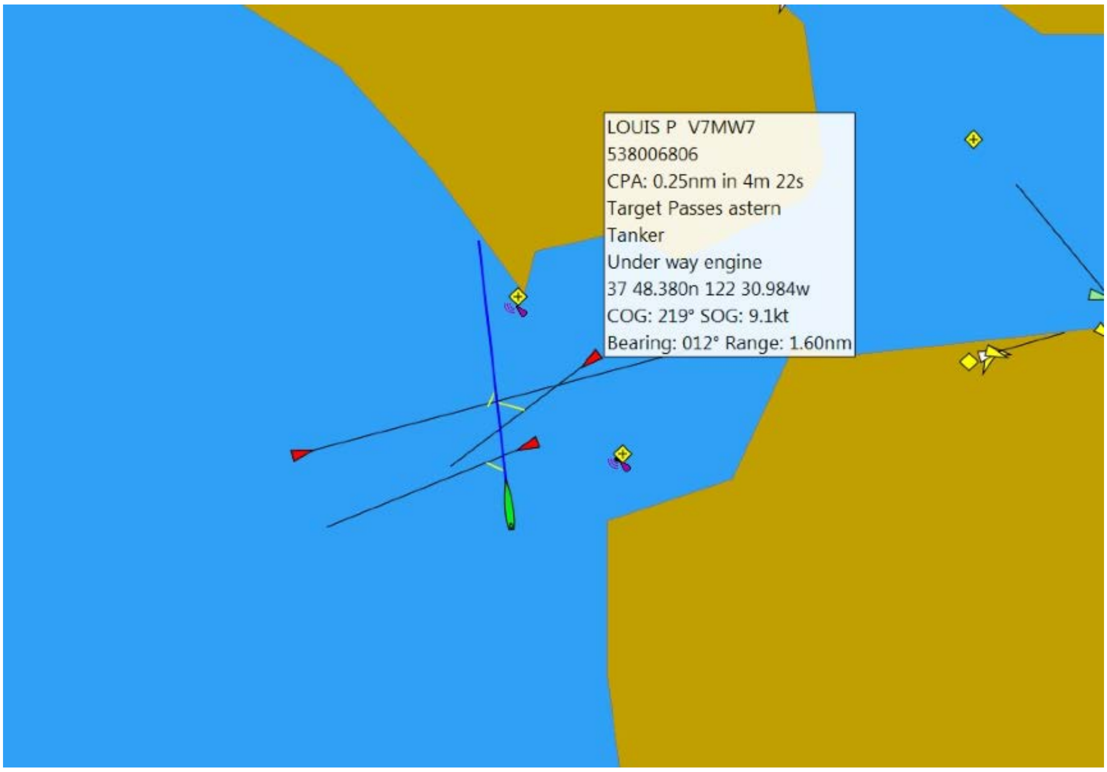

Figure 13- Expedition Presentation - Test vessel is green in centre of screen heading north - contact of interest Louis P *is to the north east exiting the strait*

96. The second method uses the yellow line, which is drawn at the predicted time of the CPA, from the test vessel to the *Louis P*'s position at the time of CPA. At the CPA *Louis P* is abaft the test vessel's beam and crossing astern. This approach seems to be the clearest for close CPA's. As the CPA gets smaller and more dangerous, the yellow line gets shorter until for a CPA of 0 the yellow line disappears.

97. The third version is provided in the 'pop-up' or 'tool-tip' window that is drawn when the cursor is placed over the *Louis P*. All the information on the *Louis P* including the CPA, time to CPA, and the passing analysis: 'Target Passes astern' is provided. This passing analysis has only been added recently.

98. Both Adrena and Expedition turn contacts red that have a CPA within a set threshold and provide an AIS table with all the relevant contact information including CPAs.

99. Crews relied on AIS as the most valuable aid to avoid collisions on a VO 65 in a high vessel traffic density area. The onboard system needs to be reliable and perform at its maximum capability. Not all crew members were fully aware of how to interpret AIS picture to quickly determine whether a contact would pass ahead or astern, and which direction to turn to increase the CPA.

Radar

100. The fitted radar is a B&G Simrad Broadband 4G, Frequency Modulated Continuous Wave (FMCW), modern generation radar. It has good target discrimination, excellent immunity to rain and performs very well as a high definition and high resolution navigation aid. This type of radar is optimised to provide 'instant on' convenience and high resolution views of harbours and channels to recreational users - which it achieves very well. Unfortunately, the long range detection capability of small

contacts is not good on a FMCW radar. The detection ranges for small targets experienced by the boats is disappointing; at times as close as 300m.

101. The radar antenna is sited on the forward face of the mast at a height of about 6 metres, which is below the first spreaders. The signal is attenuated and the receiver noise floor is increased by the loss and reflection from the headsails. This is more pronounced when the sails are wet and results in poor radar coverage in the critical area of the lee bow where the visual look-out is also degraded. Radar detections often follow an initial visual sighting.

102. The radar offers an extensive range of adjustments to fine-tune its performance under different conditions which were apparently not well understood by many of the navigators. It offers default settings for 'Offshore' and 'Harbour' which would probably be the best choice for most operators or at the very least provide a starting point from which to modify the radar's settings. From the interviews with the navigators only one or two demonstrated any confidence that they were using the radar in its optimum configuration. They knew the performance at detecting weak contacts at long range was poor and were unable to improve the results with this particular technology.

103. A simple trial was conducted on Auckland Harbour using *MAPFRE*, in good conditions with a sea state of 20-30cm. The boat approached a test target with 10 people onboard and a calculated radar cross-section (RCS) of $3.2m^2$. The radar was looking through a triple head rig of dry sails. The FMCW radar gained an occasional detection at 1nm and a solid detection at 0.5nm. A 4 kilowatt (kW) pulse radar would typically gain a solid detection at 2.8nm for this target in flat water.

104. The target boat was in the vicinity of a buoy with a TriLens Luneberg Lens radar reflector with a RCS of $10.2m^2$. The FMCW radar gained an initial detection at 2nm and a firm paint at 1.15nm. A 4kW pulse radar would typically gain a solid detection at 3.6nm for this target.

105. These results matched the detection ranges reported by crews during our interviews and confirmed the radar's unsatisfactory performance in the important areas of detection ranges and collision avoidance.

106. As a consequence some boats did not use the radar and generally considered its performance to be substantially worse in detecting contacts and tracking rain than the older style magnetron pulse radars. Navigators displayed the radar image overlaid on the electronic charts and AIS targets on the 9 inch Multi-Functional Display (MFD) at the navigation station. Boats did not have the license required to overlay the radar image on the laptop displays.

107. Only one crew relied to any degree on the radar for collision avoidance which was due to the fact that the AIS was unserviceable at the time. Consensus of the crews was that the existing radar makes little contribution to providing a 'proper look-out' and an improved radar performance should be investigated.

Preparations for Sailing into Hong Kong

108. As the crews entered the high traffic area off Hong Kong there were different approaches to the way they were managed. Two crews went to a full 'Inshore orientation' with everybody up and available. One did this for the last six hours before the finish - 'not just for speed but things change, things happen'. The other

crew had the most experienced in the area and all people were on deck when the AIS indicated they were about to enter the congested area. The main concern was nets and that they may have to gybe to sail clear.

109. Other boats appeared to have a partial solution with a full watch plus one or two extra lookouts. The navigator would generally be at the navigation station closely monitoring the AIS and in some cases the radar, as well as the boat's navigation. Everybody would be on deck at about 15nm from the finish.

110. The availability of extra lookouts and readiness for quick manoeuvres are both important factors for the PIC in determining whether the boat is sailing at a 'Safe Speed'.

Yachtmaster Qualifications

111. For a variety of reasons quite a few negative comments were directed at the new requirements to have RYA Yachtmaster qualifications. Several crews commented that the Ocean qualification was not necessary or useful for the VOR.

112. A major concern raised was that the only difference between the 'Ocean' and 'Coastal' qualifications was celestial navigation, from first principles using tables and without calculators, being added for the 'Ocean' assessment. A sextant was not provided by VOR for this edition of the race but could be carried as an optional piece of equipment. Without a sextant there was no value in the additional qualification.

113. Some suggestions were made that it would be better to offer training from experienced sailors tailored to the VOR.

Experience within the Fleet

114. Several comments were made by the crews about lower skill levels in this edition of the VOR. This is reflected in two different areas - individual offshore skills and experience, plus knowledge of the boat. The point was made that crews can be assembled quite late and are presented a complete package to join the race shortly before the start. Therefore they may not have the required experience with the boat.

115. Some of the best sailors in the world are participating in the race but few of the new entries have significant offshore or trans-ocean experience. While their participation is an overall positive for the sport, the trend is towards a different type of experience level in the fleet. There are also examples of crew members joining only days before the start of a leg after completing a rushed version of the certification requirements but with little opportunity for proper preparation.

116. A VOR 'package' consists of a fully-equipped boat prepared and maintained by the Boatyard. A consequence is that some crews are unfamiliar with all the gear provided and less likely to understand the total operation of the boat - radar, AIS, navigation systems and other systems on the boat. If the boat was being put together by the team from scratch, the team would need highly qualified builders and tuners and benefit from the experience that they bring. The crew would also be likely to come together over a longer preparation period and build up their knowledge of their boat with a greater sense of ownership.

117. Another observation is that the teams that join late have the least resources available and, for some, a relatively small budget. This means they may not have the

shore support available to other teams to assist in leg preparation, navigation, routing and other technical aspects.

Figure 14- Akzonobel with the radar antenna visible on the mast just above the top of the daggerboards - the steaming light can be seen on the mast just above the spreaders

Credit: James Blake/Volvo Ocean Race

Race Management

118. After a turbulent start to this edition of the race with the departure of Mark Turner as the Chief Executive Officer, Richard Brisius and Johan Salén took over as the President and Co-President of VOR. They both bring a great deal of experience with involvement in seven round the world races. Starting as sailors in 1989-90 edition of the Whitbread Ocean Race they, as a pair, have managed six teams including *Team SCA* in the previous edition of the race.

119. The report team met with the Race Director, Phil Lawrence, and the VO 65 Compliance Officer, Jack Lloyd. They both acknowledged that the current race schedule is punishing and too intensive. This would appear to be understood by the commercial stakeholders in the event and some changes are expected for the next edition.

120. The approach to managing the race is to depend upon comprehensive rules that have evolved through previous editions. Noting the the quality of the crews in the race, Race Management does not believe that the provision of guidelines would be of much value. With the very busy schedules some scepticism was expressed regarding crews taking note of anything other than the core race documentation and addenda.

121. Other than this report, there is not a proactive program to pursue lessons learnt from incidents or experiences during the course of the race. But there was an acknowledgement that as the race is getting 'more on the edge' in terms of

preparation and stopover time, 'it could be time to do more'. The question becomes 'how much more do we need to do' without undermining the professionalism of the sailors. Not wishing to have their professionalism challenged was a concern also expressed to the report team by some crews.

122. Race Management is pleased with the certification requirements for Yachtmaster qualifications that have been introduced for this edition of the race. They are aware that they have not been universally supported by crews but consider some incidents in this race have been better dealt with, from the organiser's perspective, as a result of having the qualifications.

123. The qualification also helps to get younger sailors into the event. Previously young sailors would join a team's large support crew and gain experience and technical skills before being part of a sailing crew. These teams are now smaller with most of the work conducted by a single team in the Boatyard. The opportunities for young sailors have diminished and the base technical skill levels of sailing crews joining the race for the first time are no longer the same.

124. With respect to alignment with World Sailing and Cat 0, Race Management believes the boats and crews exceed the World Sailing requirements most notably in the provision of the boats, all the equipment and the Boatyard servicing regime.

125. The challenge to race planners is to get the boats from the Indian Ocean to the Pacific Ocean and meet the commercial needs. All VOR editions after the 2005-06 race have had stops in Asia. The possible safe routes from the Indian Ocean to the Pacific were discussed along with how the change from the VO 70s to the VO 65s have effected the options. The new boats are slow in light winds and seek out stronger winds. The Straits of Malacca and Singapore were a major concern in the past and required complex rules and exclusion zones.

126. The Race Committee has changed the route on several occasions to avoid dangerous shores, weather and ice conditions. The Race Director reiterated the need to get the fleet where it needs to go and balance commercial considerations with those of an internationally renowned sailing event. The Race Committee was aware of the congested approaches necessitated by the Hong Kong stopover. Local authorities did not think it would be a problem but they may have underestimated the speed of the VO 65 when the wind is moderate or strong.

127. The report team discussed some of the ideas being considered as recommendations. Race Management was disinclined to implement stopping short of harbour finishes or trying to guarantee daylight finishes. They were aware that sponsors and spectators want to see the boats sailing at high speed into the harbour. Concern was expressed that stopping short would reduce the challenge and prestige of the race and that criticism had been received on this issue from some of the better performing crews. Nevertheless they retained the option to finish a leg outside of the stopover harbour and used it when required.

128. Race Management works with the Marine Rescue Coordination Centre (MRCC) network and harbour authorities in preparing for the race. The promulgation of some form of Securité message warning of the impending passage of the VOR fleet was considered possible.

External Inputs

Royal Hong Kong Yacht Club.

129. The opportunity was also taken to talk to some officials and members of the Royal Hong Kong Yacht Club and learn of their experience of racing in the approaches to Hong Kong. The club conducts an active offshore program that is centred on four major offshore races on a biennial cycle:

- The Rolex China Sea Race, 565nm Cat 1[8], Hong Kong to Subic Bay, Philippines;
- Hong Kong to Hainan Island (Sanya) 390nm;
- San Fernando Race, 480nm Cat 1, Hong Kong to San Fernando, Philippines; and
- Hong Kong to Vietnam, 673nm Cat 1.

130. The 2018 Rolex China Sea Race started on 28 March with a high quality modern fleet of 29 boats including a Santa Cruz 72, a MOD 70 trimaran, a Reichel/Pugh 66 and 2 TP 52s. This fleet and other boats compete regularly in an active race program in the approach waters to Hong Kong. They frequently encounter fishing fleets as a matter of routine. There are no special safety instructions to deal with these encounters incorporated in their race documentation.

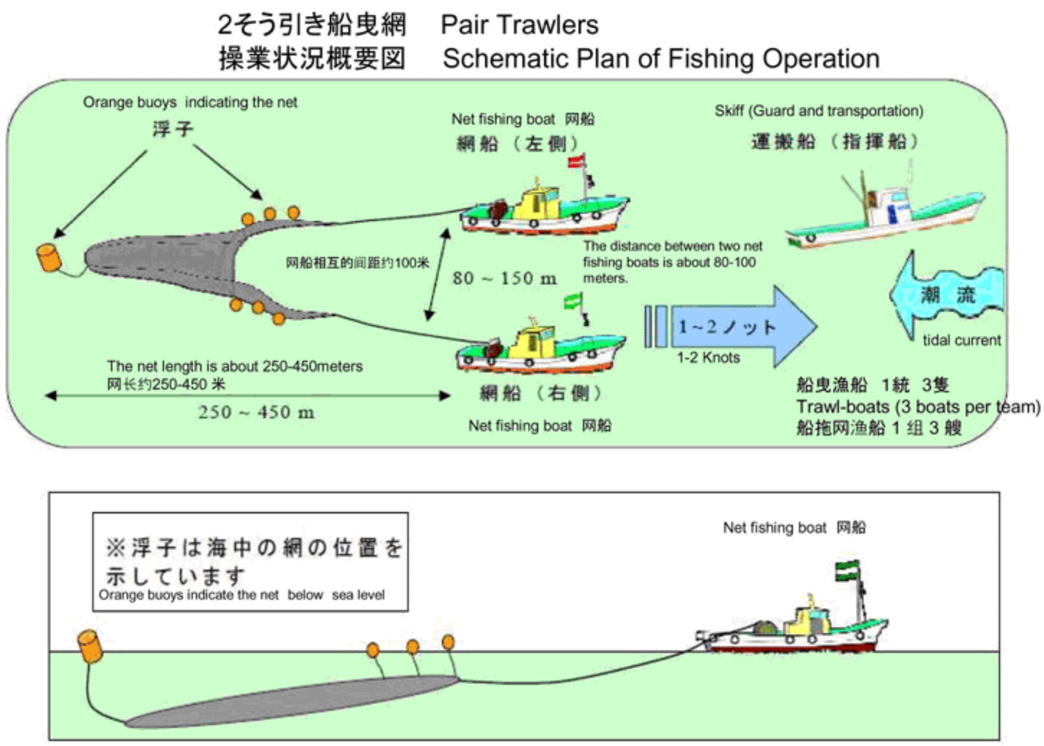

Figure 15 - Pair Trawling

131. One experienced yacht navigator and RYA Sailing School Principal, Cameron Ferguson, provided some information that aligned closely with that provided by the VOR crews. He sails on a Mills 41, with A sails and similar lookout problems to a VO 65. He has

[8] Category 1 -Offshore races of long distance and well offshore, where boats must be self-sufficient for extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without the expectation of outside assistance.

encountered clusters of up to 100 vessels in size and regards them as an ever present risk and part of their racing experience. The fishing fleets are hard to avoid but he considers crews can work their way through them with caution.

132. He has observed that most fishing boats have AIS (estimated 95+%) and he has never encountered a fishing boat with no AIS and no lights. The fishermen use bright lights to attract fish and to work on deck. Sometimes they use lasers to attract your attention and indicate the direction of the fishing gear.

133. Assessing their heading is difficult but they are normally stationary or travelling at low speed, typically 2-3 knots while fishing. Off Hong Kong the fishing vessels are usually trawling nets which have a hazard area of about 200m to 700m aft of the vessel, depending on the set of their nets.

134. Those engaged in pair-trawling can have a similar hazard distance, and have been encountered over 400m apart - greater than indicated in the diagram at Figure 15. The distance between trawlers can be scaled upwards when larger vessels are operating. Pair-trawling nets are particularly difficult to detect as they are barely visible, they are moving and the fishing vessels can be a long way from the nets.

135. Towards Vietnam, stationary nets up to 5nm long are more common and boats have to go around them. In the Philippines fish traps are a problem; a substantial steel drum with possibly a light on a stick and no AIS.

136. Cameron relies on AIS, as radar is not fitted on the boat he sails. At night he works closely with the crew on deck to correlate AIS contacts with lights. They can avoid most boats with small course alterations at reasonable range. A typical AIS detection range is 6-7nm with 4nm as the worst case. He would appreciate a functional radar and in particular the ability to overlay the AIS and radar contacts to help clarify the picture.

137. The waters off Hong Kong are more complicated than UK or American waters that Cameron has sailed but he considers them safe to sail, and less of a problem for slower boats.

Torben Grael and Brad Jackson

138. The team also spoke separately with Torben Grael (5 Olympic medals, 2 VOR (winner 2008-09)) and later Brad Jackson (6 Whitbread/VOR + Managed 1 Team + certified for the current edition). Their experiences supported that provided by the VOR crews. The difficulty of maintaining a look-out on the lee bow was seen as a major challenge that could be managed by the occasional glimpse under the sail.

139. Both were strong supporters of ‘dipping the bow to leeward’ for the helmsman to catch a look on the lee bow of anything that could be a collision risk. Torben’s worst congested traffic experiences were India and Qingdao with the Straits of Gibraltar the biggest challenge for international shipping traffic. Brad’s greatest congestion concerns were the Straits of Singapore and Malacca with nets, rubbish and unlit boats creating 2 or 3 near-misses. China was a problem for huge logs and rubbish.

140. Brad also agreed the importance of AIS as the main anti-collision aid on the boats today. Torben expressed concern over tight finishes and starts and mixing with the spectators. He remarked ‘the need for good competition but it is not worth getting someone hurt or lost’.

Figure 16 - The problem the look-out on the lee bow

Credit: Sam Greenfield/Volvo Ocean Race

Sir Robin Knox Johnston

141. World famous yachtsman and Founder of the Clipper Round the World Yacht Race, Sir Robin Knox Johnston, was approached noting that the Clipper fleet was at Qingdao at that time after a congested leg along the Chinese coast. Sir Robin noted that the Clipper boats had a different challenge to the VOR as they were slower, had a magnetron based pulse radar, that is generally thought to have better detection ranges for weak contacts, plus the sails were above the deck and you can look-out beneath them.

142. His crews estimate 85% of boats encountered have AIS. The Clipper's radar detects steel boats at 15nm and wooden boats about 2-3nm, which is as expected from a pulse magnetron radar. Fishing boats approach very close (half a boat length) to the Clippers and alter course to do so. Some of the recommendations being considered were discussed and he offered the following comments:

- feedback from a merchant ship officer of the watch was that masthead tricolour[9] lights are harder to pick out than deck mounted,
- he had a flashing masthead light on his boat 30 years ago: no challenge about IRPCAS legality,
- he considers Forward Looking Infrared (FLIR) was worth investigating, and
- unsure whether two sets of sidelights and sternlight would or would not comply with IRPCAS.

---

[9] Tricolour. An arrangement of the three navigation lights (2 sidelights and a sternlight) on a sailing boat in a single unit fitted at the masthead

6. Analysis and Findings

General Assessment

143. The VOR is a well-structured and administered race that has evolved over the past 45 years. The VO 65 used in the current edition is a rugged and generally very well equipped boat that provides excellent racing. The race, round the world, is an extreme test for boats and crews where the risk of collision in congested waters is only one of many faced during the race.

144. The risk of collision confronts all who put to sea and there are some fundamental precautions to mitigate the risk. Maintaining a 'proper look-out', proceeding at a 'safe speed', displaying navigation lights and when appropriate taking early action as required by IRPCAS are paramount.

145. Following interviews with the skippers and navigators from each boat, and others, the report team has gained an appreciation of their experience of sailing a VO 65, or near similar boat, at night through dense traffic.

146. The assessment of the report team is that the risk in areas such as the approaches to Hong Kong is manageable. A very high percentage of the boats in this waterway have AIS and some form of lighting. The VO 65 is highly manoeuvrable, fully crewed, fitted with AIS and radar and it is possible to maintain an all-round lookout. An assessment of other congested areas would depend on some knowledge of the local fleet and its behaviour that may require some extra precautions to be implemented.

147. On the negative side the all-round visual lookout from a VO 65 is awkward with a large arc blocked by the sail plan, and requires special flexible techniques adapted for the existing circumstances, for it to be effective. The radar's performance is poor in detecting small contacts at reasonable range and the AIS transceiver has been prone to reliability issues and degraded performance. In addition the navigation lights are not considered to provide an adequate warning of the boats presence even though they comply with IRPCAS for a 22.14m boat under sail.

148. The risk of collision could be further reduced by some relatively simple means to improve the 'look-out' and 'enhance the visibility of the boat'.

Possible Enhancements

149. In talking with each crew, comments were sought on what enhancements could be made to improve the safety of navigating through congested waters. Most responses centred on an improved look-out and providing a better warning of the boat's presence. The report team also sought comments on what other crews had suggested and their own initiatives that were being considered.

Improved Look-out

150. The look-out from a boat is not limited to a single means such as a visual look-out. A more effective look-out will be provided by using additional sensors that include hearing, radar, AIS and a radio watch. The idea is to build layer upon layer of look-outs that will cover weaknesses that may exist in any one layer and thereby prevent any object that might be a risk to the boat being undetected.

Visual look-out techniques

151. When available, visual look-out will always remain the most important means of appreciating the situation as it provides the best sense of situational awareness that is very important at sea.

152. Crews need to assess the effectiveness of the look-out and associated risk based on the visibility, the sails set, the level of traffic and speed. In light traffic and good visibility conditions the occasional glimpse to leeward by the trimmer or grinder could be sufficient but may take 30 seconds or longer. In heavier traffic or with limited visibility a dedicated lookout may need to be placed to leeward, if there is not too much spray, or the back lee corner of the boat, to continually try to gain a glimpse forward and to leeward.

153. In some conditions there will be a residual blind arc of about 20°-30° that may be able to be viewed by ‘dipping the bow’ up to 30°to leeward for the helmsman to gain a view. The dip frequency would need to be adjusted depending on the four variables: speed, visibility, traffic density and the look-out arc obscured by the sails that are set.

Figure 17 - The challenge for a leeward look-out
Credit: Martin Keruzore/Volvo Ocean Race

154. If a proper look-out cannot be maintained, the PIC will have to consider changing the variables that can be controlled: sails and/or speed to slow down or improve the look-out. This consideration would also be influenced by the effectiveness of the radar, AIS and any other means of looking-out.

155. Crews suggested that an intermittent 360°visual look-out can be maintained in nearly all conditions. The disadvantage is the drop-off in speed when ‘dipping’ and the requirement, at times, for a dedicated look-out.

156. While most crews indicated they carried out a close variation on what appears best practice, the main difference seemed to be the degree of ‘dipping’. Some crews only mentioning a few degrees; and that would appear to be inadequate. In addition, not all boats used a dedicated lookout aft when the circumstances might have dictated or the look-out to leeward became ineffective through spray and ‘green’ water.

157. The report team considers that all crews should continue to refine their techniques that maximise the effectiveness of the visual look-out in the prevailing circumstances, including adequate 'dipping the bow' and the placing of a dedicated look-out when required.

AIS

158. AIS is the most important navaid in preventing a collision with another vessel fitted with an active AIS transponder. It has an unencumbered 360° field of reception from the masthead and can provide detection ranges of about 10nm to a yacht or fishing boat with a Class B unit, or 30 miles to a ship with a Class A unit.

Figure 18 - Photo of the 'tunnel' MFD just inside the cabin available to the crew on deck
Credit: Photo by Chuck Hawley 2014

159. As stated in Section 5 unserviceability and degraded AIS performance have been problems within the VOR fleet. These are believed to be due to the BNC coaxial connector and antenna mounting that is used. BNC coaxial connectors are "quick connect" bayonet fittings. They are neither weather resistant nor vibration proof and are ill-suited for this application where the connector is serving as the physical mount for the VHF antenna.

160. The AIS data can be displayed on several systems within the boat - Adrena, Expedition and on the MFDs. At Section 5 an overview of the Adrena and Expedition AIS presentations is provided. Each presentation is quite different and personal preference is likely to dictate which system is used. In congested areas the situation and evaluation of an anti-collision plot can become confusing. A high level of operator expertise is required to assess CPAs and appropriate collision avoidance action by all crew members who might be required to stand an AIS watch. There

needs to be additional proficient operators onboard other than the navigator, to provide a relief particularly in congested areas.

161. A safety workshop or training session should be provided to train crews in the use of AIS. It is considered important for the crew member nearest to the 'Tunnel' MFD to be able to provide accurate and precise information on collision avoidance. In addition, feedback could also be provided to the major navigation system providers - Adrena and Expedition - regarding recommendations on improving the user interface with their systems. They have proved responsive to such feedback in the continuing evolution of their systems.

162. Noting the importance of the AIS, the coaxial cable should be tested for attenuation at each stopover. A proposed procedure, prepared by Stan Honey, is attached at Appendix 5. The antenna connection at the masthead should be made via a more rugged and weatherproof connector such as a TNC or N connector instead of the current BNC connector.

163. In addition the performance of the AIS on all boats could be monitored by Alicante Race Control through registering the VOR fleet with MarineTraffic.com and observing detection ranges of boats when in range of shore stations. This would provide a comprehensive end-to-end test of the systems serviceability and performance. Any degraded results should be investigated and rectified at the first available opportunity.

164. The report team considers that the unserviceability and degraded performance of the AIS systems significantly reduces the effective look-out from a VO 65. The suggested antenna changes, training workshops, testing and monitoring are considered necessary, to ensure the availability of AIS and its valuable contribution to collision avoidance[10].

Radar

165. The FMCW radar, fitted to the VO 65, is not the optimum radar for offshore ocean racing and its performance in the collision avoidance role is poor. While FMCW radars have very good high resolution, this is less important to ocean racers who would prefer to have enhanced target detection range rather than high definition.

166. In selecting a replacement radar it should be tested against a conventional pulse magnetron radar with the same dome size. The aim is to ensure that the new radar works at least as well as the conventional pulse magnetron based unit for the detection of small targets at maximum range. New design pulse compression radars might work well but this needs to be confirmed by comparison tests with conventional pulse magnetron radars.

167. Navigators and other crew members should be offered training with the selected radar on how to set it up for optimum performance in gaining the maximum

[10] The report team became aware of the AIS reliability and performance issues early in preparing the report. Email advice was forwarded to VOR on 11 Apr 2018 suggesting a get well program. Stan Honey also engaged with Boatyard staff providing a Coax Testing procedure for the system. The necessary improvements are understood to have been implemented during the Itajaí stopover and included a back-up AIS System.

detection range of a weak target, precipitation tracking and the use of guard zones[11].

168. The report team considers that radar should provide an important back-up to AIS and a valuable contribution to a proper look-out in an event such as the VOR. Training in its proper use is also considered important. The existing FMCW radar should be replaced with a pulse or pulse compression radar.

Forward looking infrared (FLIR)

169. FLIR is potentially a very exciting sensor, touted as the 'Sixth Sense', with the ability of turning night into day and resolving the visual look-out problems on sailing boats with over lapping headsails. The technology has been available for many years and is currently marketed in many commercial and recreational marine applications. The disadvantage is that the cameras have been rather bulky but the technology is improving and a system suitable to operate on a racing yacht might be available soon.

Figure 19 - Daylight FLIR screen from a Manly Ferry on Sydney Harbour - Headland (Right Hand Edge) at top left of screen is 1.2nm, land beyond is at a distance of 2-3nm

[11]A guard zone can be set up around the boat using the guard feature of radar. If the targets change inside the zone that you set, an alarm sounds.

170. The application on a yacht presents a number of challenges. To gain an unimpeded view, not blocked by sails, it would need to be sited above the head of the headsail. In a VO 65 with masthead sails, this would require the camera to be placed on the masthead, which is already crowded. The movement at the masthead could make it difficult to stabilise the image and present a clear picture to a display on the boat.

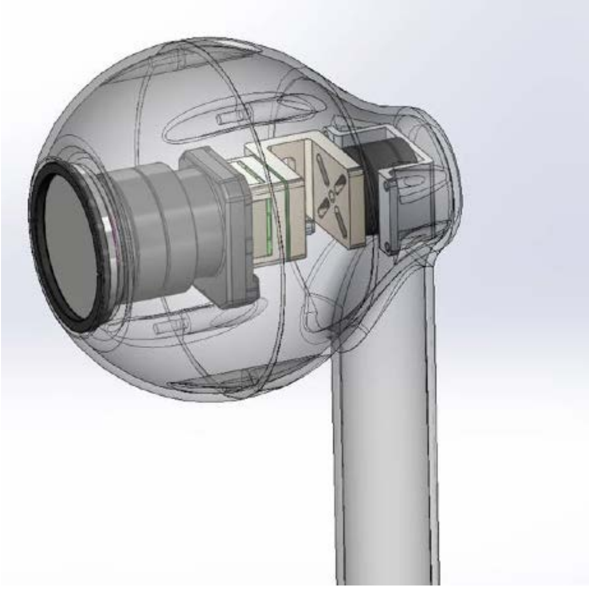

Figure 20 - The FLIR Systems concept

171. Rather than amplify weak light like night vision products, FLIR sensors are sensitive to electromagnetic radiation in the IR band from 7.5 to 13.5 micron wavelengths (so-called long-wave infrared). This allows differentiation of objects based on temperature so that humans, engines and other warm items, as well as cold items such as ice, show up against the ocean and/or land.

172. FLIR would be a very useful sensor in searching for a person overboard.

173. FLIR cameras are normally fitted in a remotely-controlled gimbal mount that allows pan and elevation adjustment. The field of view is nominally 24 degrees wide by 18 degrees high. Narrower fields of view have a longer range while a wider field provides more situational awareness and less need to point the camera in a particular direction other than right ahead or for a VO 65 on the lee bow.

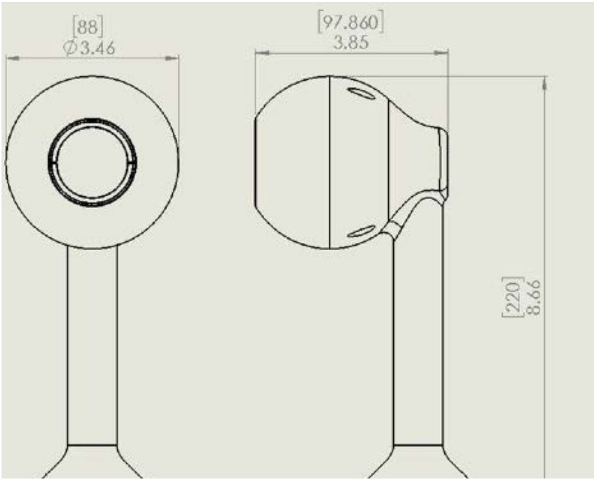

Figure 21 - The dimensions 88mm (3.46 inches) by 98mm (3.85 inches), the pole 220mm (8.66 inches) could be longer, shorter or curved

174. Chuck Hawley of the report team met with a Vice President and a Director of FLIR Systems, Inc. at Galeta CA. He discussed the adaption of the technology for use on an ocean racer. An encouraging development is a substantially smaller sensor which will shrink the camera enclosure. This should make a masthead fixture feasible but the remaining issues associated with a masthead fitting still need to be resolved. There was a degree of confidence that this could be achieved.

175. FLIR Systems has approached the challenge enthusiastically and their initial proposal is a concept using one of their products, a 'Boson' camera, that would have a direct dynamic roll

correction motor in the back of the camera and would keep the image horizontal in all conditions. The pitch would be controlled digitally, allowing the image to be cropped to keep the region of interest stabilised. The enclosure would have no external moving parts and would be robust. The unit could be connected using power over the ethernet.

176. When discussed with the crews there was support for forward looking infrared and what it might be able to do. A few crews had experience in using the sensor in other non-racing vessels. The Boatyard team mentioned that the use of FLIR had arisen in discussions with International Monohull Open Class Association (IMOCA) and that association may be looking at its application for their boats.

177. The report team considers that VOR should investigate and determine the practicality of installing a forward looking infrared camera in a location which provides an unimpeded look-out to assist collision avoidance and the recovery of a person overboard. VOR should use its position to strongly support and encourage the introduction of this technology to offshore racing.

Clear panels in headsails

178. In an attempt to resolve the look-out blanking problem created by the headsails, suggestions were received proposing clear panels being placed in the headsails as are often used in other classes that have a similar look-out problem.

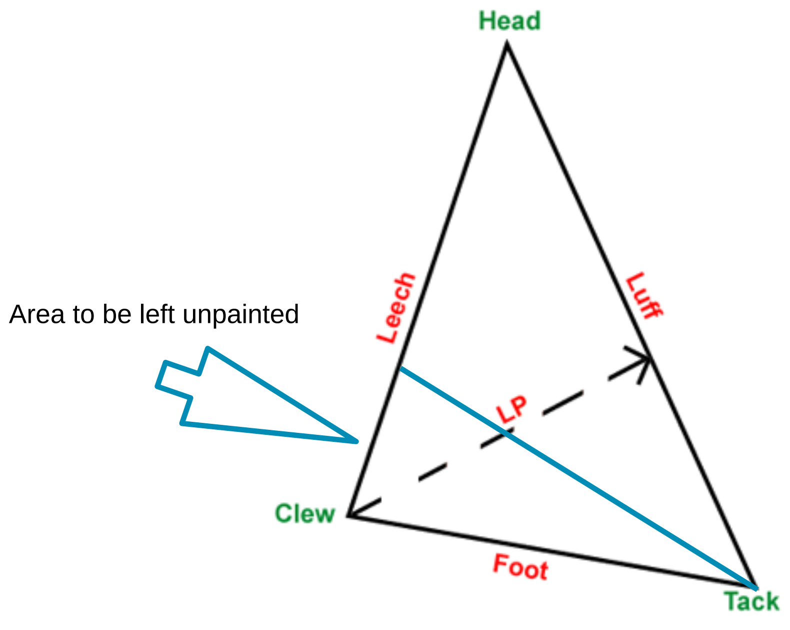

Figure 22 - Named parts of a headsail - with the marked area considered to be left unpainted

179. At present all of the sails with the exception of the A3 are painted with a selection of base colours that are then used as a background for the Volvo and other sponsor signage. When this process is complete the sails are opaque and it is not possible to see any light through them. A variation of the clear panels was also suggested, proposing a large triangular section on the foot of the sail be left unpainted, clear of any signage and possibly translucent. The triangle would have a corner at the tack

and clew of the sail and the third corner about a third of the way up the leech from the clew.

180. The report team made contact with Ken Read[12], President of North Sails Group, the loft which produced the sails for the VO 65. His advice was that a window in the MHO and FRO would not work as the bottom of the sails 'take a beating' and a clear panel, or section of 3DL[13] would not last more than a third of the life of the sail. With respect to leaving a section of the sails unpainted, he thought the MHO was sufficiently opaque that the logo paint did not really change much and you would be unlikely to see any lights through the unpainted sail.

181. The report team considered that it was not worth pursuing clear panels or unpainted sails any further.

Change sail plan

182. Another suggestion received was to change the sail plan on the boats to improve the look-out beneath the sails. This would require shortening the luff perpendicular (LP) and raising of the clew of the MH0, FR0 and A3 .

183. Ken Read's commented that raising the clew of the MH0 by reducing the LP would work but the boats have a low aspect rig. He made the point that a VO 65 is already short on sail and such a change would add to the criticism of the boat's speed - making the VO 65 even slower. The option of a taller replacement rig with shorter LP sails would work but would be expensive unless the rigs and sails were being replaced anyway.

184. In considering the replacement for the VO 65 in the design stage, Ken suggested a bigger rig and less overlap would provide more visibility. He made the comment that the MH0 is one of the most used sails around the world and as boats get faster the MH0 is being preferred as the downwind sail instead of any typical A sail. This was supported by comments from the crews on their current sail preferences.

185. The report team considered that the idea of raising the clew has merit but its application to the VO 65 would depend on decisions regarding the rig or sail plan of the boat. With respect to any replacement design or a new class for the event the issue of all-round visibility and the advantages of a bigger rig, less overlap and a raised clew should be seriously considered.

Enhanced Visibility of the VO 65

186. At Section 4 the navigation light requirements for a sailing vessel and the arrangements onboard a VO 65 are stated. If being approached by or overtaking a VO 65 at night, all that is visible will be a single red or green or white light, 30 metres in the air. There is unlikely to be any engine noise and the only noise the groaning sounds that emerge from the sail trimming on a carbon boat.

187. An active AIS transponder does assist in alerting other boats fitted with AIS of a VO 65's presence but the onboard system has to be serviceable and, to be of greatest assistance, should not be degraded. The effectiveness of AIS in warning another

[12] Ken Read is a renowned sailor as well as sailmaker, having won 9 World Championships and competed in 2 America's Cup programs and 3 VOR

[13] 3DL -a sailmaking technology developed by North is more translucent than the 3Di material used for the VO 65 sails

vessel of your position also depends upon the AIS display equipment available in the other vessel. This would be very varied in the types of vessels in congested waters such as those near Hong Kong. Many vessels may have a relatively inexpensive AIS beacon to indicate their own presence but no means of receiving or displaying other AIS signals or data. Navigation lights remain a very important means of indicating a boat's position to other vessels.

188. Even if the single navigation light is detected it is difficult to gain an accurate indication of the approaching boat's aspect, whether you are fine on the bow or broad on the beam, or gauge its range from a single LED light at an unusual height above the sea. The situation can be made worse if the VO 65 is travelling fast as the range could close quickly and the relative velocity and collision avoidance is confusing to assess.

189. There are a number of issues that need to be addressed with the arrangement of existing navigation lights and the possibility of enhancing the presence of a VO 65, when appropriate, such as in areas of high traffic density.

Navigation lights

A sailing vessel underway

190. The three lights fitted at the masthead are separate Hella light fixtures with their own LED globes. They differ from the 'combined into one lantern' that is permitted in IRPCAS Rule 25 but restricted to a sailing vessel of less than 20m in length. The combined lantern is assumed to have been a means of minimising power consumption

Figure 23 - VO 65 Navigation Light fitting clamped on to the vertical masthead unit that is fitted to the top of the mast - viewed from the starboard quarter, showing the sternlight and starboard sidelight

Credit: Chuck Hawley

on smaller vessels many years ago, as the regulations mention a single vertical filament in the lantern, at Annex I

191. Lights at the masthead overcome two potential problems. Firstly the lights cannot be blanketed or obscured from view by opaque sails and secondly there is not a backscatter of the light reflecting back from the sails and degrading the night vision of the crew on deck. If the sidelights were close to deck level and obscured by the sails the VO 65 could effectively be unlit on the lee bow.

192. There are no restriction on the horizontal or vertical positioning of sidelights or stern lights for sailing vessels at IRPCAS Annex I. There is however an archaic reference to requiring inboard screens being painted matt black for the sidelights of a vessel 20m or more in length, to accurately define the prescribed arcs.

193. The screen requirement is no longer considered relevant with modern light fittings and ultra precise horizontal and vertical cut-off angles incorporated in their design, as advised by the manufacturers. As long as the lights show over the correct arcs, the current arrangement for a VO 65, when sailing, is considered to comply with IRPCAS.

Power driven vessel

194. When a VO 65 is operating as a power driven vessel at night, that is a power driven vessel of 20m or more in length, there are a number of restrictions regarding the vertical and horizontal positioning of lights. A VO 65 has a combined fitting on the forward face of the mast just above the first spreaders which houses both the steaming light[14] and the deck illumination lights and both are operated independently.

195. Annex I of IRPCAS requires that:

- the steaming light be not less than 6m above the uppermost continuous deck,
- the sidelights are to be lower than the steaming light and not greater than 3/4 of the height of the steaming light and shall not be so low as to be interfered with by the deck lights,
- the sidelights are to be forward of midships,
- the sidelights shall not be placed in front of the steaming light,
- the sidelights shall be placed at or near the side of the vessel, and
- the sidelights require screens painted matt black (still considered not relevant)

196. The steaming light complies but the sidelights do not and it would be very difficult to comply fully. Some of the other modern offshore racers, over 20 m in length, face the same issue and comply as closely as practicable by having a second set of sidelights close to deck level and fitted on the pulpit. They also have a sternlight, again fitted close to deck level and do not generally have a sternlight at the masthead.

197. When under power these boats use the deck level sidelights and the normal deck level sternlight. With a steaming light on the mast this approach meets the required vertical separation, but the sidelights are forward of the steaming light and in that

[14] The correct IRPCAS term for this 'white light showing an unbroken light over an arc of the horizon of 225°' is the 'Masthead light' but as there are a number of references to lights at the masthead it is referred to as a 'Steaming light' in this report. 'Steaming light' is often used colloquially to refer to the 'Masthead light'

forward position are near the side of the vessel. This is the situation with most modern yachts and production boats and, as it has not been challenged over many years, it would appear to be acceptable.

198. In addition to the sidelights and stern light at the top of the mast on a VO 65, a second set of lights, near deck level, could be fitted. These lights could be used in conjunction with the navigation lights at the masthead to make the boat more visible in circumstances such as high density traffic areas or in harbour. The two visible lights, either red, green or white, could also provide visual reference that might assist in gauging the distance of a boat when sighted at sea.

In harbour

199. The visibility of the navigation lights at the masthead only can be more of a problem in the harbour. The distances between vessels are usually closer and crews of other boats are not looking 30m in the sky. The use of lower fitted sidelights and sternlight would improve the situation and make the yacht more visible to nearby traffic. The lower sidelights can, however, be obscured by low footed headsails and A sails, though there maybe some reflected glow that might at least make the boat visible at close range.

200. To address the obscuring of the low sidelights and generally provide better awareness of the boat's presence in a harbour, both sets of sidelights and sternlights could be used. IRPCAS does not prohibit a second set of navigation lights and vessels often duplicate restricted in ability to manoeuvre or other special tasking lights, especially when a single set of lights could be obscured from an all-round view by a solid mast or other superstructure.

What the regulations say

201. IRPCAS Rule 20, Part C Lights and Shapes, *Application;* does state: "…no other lights shall be exhibited, except such lights as cannot be mistaken for the lights specified in these Rules or do not impair their visibility or distinctive character, or interfere with the keeping of a proper look-out." The intent is repeated in Rule 36 *Signals to attract attention;* which states: '…any vessel may make light or sound signals that cannot be mistaken for any signal authorised elsewhere in these Rules, …"

202. The key would appear to be whether a second set of sidelights and second sternlight could be mistaken for any lights elsewhere in the rules. Noting the vertical separation from the deck to the masthead relative to the size of the boat, it is unlikely. If the boat is on an angle of heel of 30° the lights may not be in a line. There could be a lateral separation of up to 15m but still with a vertical separation of about 26m. Both lights would display the same bearing movement and appear to be on the same boat.

203. An observer in another vessel could be confronted by two red or two green lights if being approached by the VO 65 or two white lights if overtaking the VO 65. These lights might be in line or with some lateral as well as the vertical separation. There are combinations of two red lights - a vessel not under command or aground or the side of a dredge where the obstruction exists. Similarly two green lights could be confused with minesweeping operations or the side of a dredge on which another vessel may pass.

204. All these lights, with the exception of a vessel not under command and not making way, would be accompanied by other distinguishing lights. The lights would also normally be in line and a lot closer together. The minimum vertical separation for these distinguishing lights for a vessel over 20m in length is 2m.

205. There is a possibility that the the two overtaking lights, again either in line 30m apart or with a lateral separation of up to 15m and a vertical separation between 26m-30m, could be mistaken as the steaming lights of a vessel over 50m in length at a range before the sidelight(s) came into view. The overtaking arc is the arc of least danger and if necessary a single overtaking light could be displayed - at the masthead at sea and near deck level when in harbour. Annex I of the IRPCAS does not specify any vertical separation for the overtaking light in relation to the steaming light or sidelights.

206. The second set of sidelights and overtaking light near deck level would not comply fully with the IRPCAS when operating as a power driven vessel. The lower sidelights would still be in front of the steaming light. This would be consistent with most modern yacht designs.

207. Section 14 of IRPCAS Annex I states: '…the installation of lights on board the vessel shall be to the satisfaction of the appropriate authority of the State whose flag the vessel is entitled to fly.' VOR could seek the appropriate exemption or approach World Sailing to make a broader petition to the International Maritime Organisation to update some parts of IRPCAS, regarding lights, that are no longer appropriate.

208. The report team considers that VO 65s should be fitted with a second set of sidelights and a sternlight near deck level to enhance the presence of the boat at night in areas of high vessel traffic density and in harbour. The additional lights could be used, at the discretion of the PIC, in conjunction with the lights at the masthead, whenever warranted by the prevailing circumstances.

Figure 24 - Life as a leeward look-out on Turn the Tide on Plastic

Credit: James Blake/Volvo Ocean Race

Masthead flashing lights

209. The second set of navigations lights only make a modest improvement to visibility of the boats and provides a partial solution. More is needed to enhance the boat's presence and make other vessels aware. An idea put forward was to fit an all-round flashing white light at the masthead. This is not a new idea and has been used in the past by singlehanded sailors, including Sir Robin Knox Johnston 30 years ago. Again such a light is suggested as an optional light that could be activated by the PIC when considered necessary in the prevailing conditions - such as congested waters or a crowded dark harbour.

210. The flashing light would need to be constructed with shields that prevented the light interfering with the night vision of the crew on deck. Further the duty cycle of the flashing light needs to be sufficiently low so as not to obscure the navigation lights at the masthead.

211. Crews were generally supportive of the flashing light, though one comment was received that it may not be useful in harbour. While there could be less benefit in harbour there still maybe times when there is need to signal the presence of a sailing boat capable of high speeds. One crew did not support the flashing light as it was thought 'the problem existed with the boat doing 20 knots'. While this might be true the consensus was that the situation was safer when vessels in close company were both aware of each other's presence.

212. Comment was also made questioning compliance with IRPCAS. Rule 36 *Signals to attract attention,* makes specific provision if necessary to attract attention of another vessel. This is what is trying to be done. There are a number of relevant provisos:

- the light cannot be mistaken for any other signal authorised elsewhere in the rules,
- cannot be mistaken for any aid to navigation, and
- the use of high intensity intermittent or revolving lights, such as a strobe lights, shall be avoided.

213. The only single flashing lights required by IRPCAS are in Rule 23: a flashing yellow light on an air-cushion vessel and a high intensity all-round flashing red light on a wing-in-ground craft. There are some other flashing lights used by appropriate authorities as special rules, supplementing IRPCAS. While flashing lights are used as aids to navigation, the movement of the VO 65, the height of the light above the water and in most cases (other than if used in a harbour) where the vessel is sighted, would eliminate the boat being mistaken as an aid to navigation. The situation would also be quickly resolved by the other lights displayed by the boat and its movement.

214. With respect to the lights to be avoided. IRPCAS at Rule 21 defines a flashing light as 'a light flashing at regular intervals at a frequency of 120 flashes or more per minute'. The main difference between a flashing light and a strobe light is the frequency. A flashing light by definition operates at about 2 hertz (Hz) or cycles per second, whereas most strobes operate above 10Hz and at these higher frequencies can cause dizziness and trigger photosensitive epilepsy seizures.

215. Another concern expressed about the acceptance of a flashing white light was that it could be interpreted as a distress signal. However, a flashing light, other than SOS, is

not listed with the Distress Signals at Annex IV of IRPCAS. In more general use a flashing white light is regarded as a signal to attract attention.

216. On balance there appears to be no reason why a flashing white light could not be fitted at the masthead. It would certainly enhance the presence of the VO 65. The report team considers one should be fitted to attract attention as an anti-collision warning light and used at the discretion of the PIC when required by the prevailing circumstances.

Illuminated mainsail

217. Another idea put forward during the interviews was to illuminate the top of the mainsail. Some crews spoke of occasionally using the deck illumination lights to make the boat more visible but the disadvantage was that the lights affected the night vision of the crew on deck and the overall effectiveness of the visual lookout.

218. The mainsail could be illuminated with two lights on the upper side of the top spreaders facing up and aft towards the top section of the mainsail, including the VOR logo. The lights would be directed away from the crew on deck and unlikely to greatly increase the ambient light. The effectiveness might depend on the colour of the sail, with the darker sails reflecting less light and providing less illumination.

219. The illuminated mainsail would also assist other boats in estimating the range of the VO 65.

220. The visibility of the boat would be enhanced: not as well as the flashing light but better than the additional set of lower placed navigation lights. The mainsail light could be used in conjunction with or separately to the other proposed lighting enhancements. The PIC would have available three additional lighting options to use to advertise the boat's presence in the particular circumstances: possibly the flashing light at sea and the lit mainsail in harbour with the upper and lower navigation lights available in both situations.

221. The crews with whom the illuminated mainsail was discussed were supportive of the idea and had no objections as long as their night vision was not affected.

222. The report team considered a set of lights should be installed on the upper spreaders to illuminate the top of the mainsail. Combined with the additional navigation lights and masthead flashing light, the PIC would have available a suite of measures to enhance the visibility of a VO 65 in a wide range of circumstances.

Securité broadcasts from boats

223. The final suggestion canvassed to enhance the presence of the boat was a Securité[15] broadcast on VHF Channel 16 by individual boats when approaching or passing through a particularly congested area where there was concern regarding collision avoidance.

224. The broadcast would need to be simple and clear, along the lines:

> "Securité Securité Securité This is Volvo Ocean Racer ……………... transiting the ……... Strait under sail at speeds around 20 knots. I will keep clear of you. Please

[15]Securité Warning: A radio call that usually issues navigational warnings, meteorological warnings, and any other warning needing to be issued that may concern the safety of life at sea, yet may not be particularly life-threatening.

switch your lights and AIS on. I have a flashing white light at the masthead. Please do not pass close ahead of me. Securité Securité Securité"

225. Language may be a problem and a set of recordings would probably need to be prepared for each expected congested area in advance of each leg. Selecting the VHF channel that might be used as a working channel could also be a problem, though guard should be maintained on Channel 16.

226. The report team considered this option is always available to a crew should it be considered necessary and did not warrant being pursued further as a formal recommendation.

Race Management

Sharing information

227. The report team observed an interesting relationship between Race Management and the competing crews. Race Management showed considerable respect for the professionalism of the crews, their sailing achievements and experience. They did not want to undermine this experience through issuing general instructions or guidelines which were over protective or interfering with personal choice. Consequently, briefings and formal guidance were largely restricted to what was in the rules and race documentation.

228. Although the report team only gained a limited snapshot from crew interviews and a few days in the race village, the crews appeared to be seeking more collective interaction with Race Management. Even the most experienced crews made comment that there were insufficient and inadequate briefings to share information to provide some local knowledge or specific information related to the route; that might include fishing fleet activity or local customs which could affect vessel safety. There was a willingness among the crews but no structured opportunity to share previous experiences within the fleet and to advise and assist those less experienced.

229. The current Skippers' Briefings before a leg are limited to the skippers and navigators to facilitate frank feedback. They are short, lasting 20-30 minutes. There is not much of a briefing but a confirmation of the current documents and latest updates with an overview of the weather and any new news.

230. The one exception has been a briefing and detailed instruction provided for the transit from Hong Kong to Guangzhou. This was well received and appreciated with the crews learning a lot about the behaviour of local vessels including superstitions and the tendency for local vessels to pass close ahead.

231. There appeared to be some frustration from the crews that this important interaction was not happening routinely and more often. Favourable reference was made to the previous edition of the race with valuable briefings on what to expect in the Straits of Singapore and Malacca.

232. Race Management emphasised that they sought and were available for individual meetings with every skipper at each stopover where the skippers could frankly express any concerns and make any recommendations thought necessary. Race Management also established a regular dialogue throughout the race with both the navigators and shore based navigators where any concerns and recommendations could be expressed.

233. Some crews recalled more expansive race briefings where an agenda was prepared and distributed among some navigators for comment. This allowed items important to the crews to be included and discussed with useful interaction between all crews and Race Management - a collective experience in facing the common real challenges of sailing a boat round the world.

234. With respect to Hong Kong, one crew reported to 'have been sailing in these waters for over 20 years and noting nothing out of the ordinary this time' - 'you can't sail around Asia with the same level of confidence that you sail with in other areas'. The point was then made that there had been no opportunity to share this experience among the other crews.

Figure 25 - Dongfeng Race Team - powering under a well set triple head rig
Credit: Jeremie Lecoudey/Volvo Ocean Race

235. Noting the generally accepted reduced trans-ocean experience and lower level of boat knowledge in the crews, such briefings would appear to be even more important. There may be more of a role for Race Management that could include soliciting information from the more experienced crews. The gap in knowledge is not being filled with Yachtmaster training or other pre-race certification.

236. How much Race Management should do is a difficult balance to strike and is often a point of contention within the sport more generally. In the VOR it is more complex as there is such a diverse range of experience levels and the challenge is 'Life at the Extreme'. This is further complicated when the more experienced crews have the most shore support to assist in the planning of a leg and need little additional assistance. The least experienced crews generally have less support and would benefit from more assistance coordinated by Race Management.

237. As a separate issue, there appear to be two digital Noticeboards available for race documentation: one available through the website and another with some controlled access through Smartsheet Inc. A reference section would be easy to add to the

Noticeboard and be of benefit to include relevant reports, articles or documents that may assist teams preparing for the race. Internal reviews of incidents that occur during the race could also be included to assist in capturing the lessons to be learnt. Crews may also provide some material that they wish to share.

238. The report team considers that the race briefings should be more comprehensive and informative regarding the next leg. In addition a section on the digital noticeboard should be used to place reports and other documents with lessons and guidelines that may assist crews in preparing for the VOR

Training and Yachtmaster qualifications

239. The requirement for RYA Yachtmaster qualifications was introduced to address the concern of insurers and some national bodies that no formal mariner qualifications were required for the PICs or crews in earlier editions of the race. There does not appear to be a regulatory requirement for crews of 'recreational' or 'leisure' vessels to hold any specific certificates of competence. Previously there was an experience requirement for a percentage of the crew that was easily satisfied.

240. For the 2017-18 VOR the PICs and navigators had to hold the RYA Yachtmaster Ocean qualification and the rest of the crew had to have the RYA Coastal qualification. On paper there is a considerable difference between the 'Ocean' and 'Coastal' qualifications. The 'Ocean' requires the RYA Yachtmaster 'Offshore' as a prerequisite. The 'Offshore' requires much more qualifying seatime: basically 50days, 2,500nm compared with 30days, 800nm for the 'Coastal'. The 'Offshore' also has a longer (8-12 hours) and presumably more stringent practical exam than the 'Coastal' (6-10 hours).

241. The 'Ocean' qualification is gained following an oral and written assessment of sights taken at sea during a qualifying passage. About 70% of the test is celestial navigation. There are two other sections on voyage planning plus crew and yacht management which make up the rest of the exam.

242. Noting the people sailing in the VOR as PICs and navigators are experienced professional sailors, they easily exceed the qualifying seatime and have the experience to satisfy the other components of the 'Ocean' exam. For these people, the difference between the 'Coastal' and 'Ocean' is the celestial navigation component that may have no relevance to their participation in the VOR. The general opinion of the crews was that the training was of no practical benefit other than obtaining a certificate.

243. The positive side to the RYA qualifications is the regulatory cover provided to VOR. In many parts of the world a holder of a Yachtmaster 'Ocean' Certificate of Competence can skipper yachts up to 200gt[16]. The RYA certificate is a British qualification but widely accepted around the world. If used commercially some additional courses are required as well as some possible local endorsements where the yachtmaster is operating.

244. The RYA qualifications provide a graded assessment of the offshore fundamentals of safety, boat handling, seamanship, navigation and boat management. They provide

[16] gt; gross tonnage is a nonlinear measure of a ship's overall internal volume used in the regulation of commercial shipping

an ideal platform for recreational sailors and people wishing to be part of commercial sailing.

245. Other than celestial navigation, there is a need for all the RYA 'Ocean' skills as a PIC or navigator when racing in the VOR - plus a lot more. The yachtmaster qualifications are obtained on boats with standard chart plotters. There is only a requirement for a general understanding of AIS. Radar may not be fitted to the boat used to assess the 'Offshore' skipper or included in the training. Instruction in radar is available as a separate RYA course to a basic standard.

246. The VOR environment is quite different from a commercial yacht or recreational vessel. VOR is highly regulated and rules based. The boats are provided well equipped and maintained to a high standard by the organiser. Their operations at sea are continuously monitored very closely from a race centre. There is a great deal of back-up and redundancy fitted into the critical systems and there is a highly sophisticated communications network available. All the provided equipment and systems are contemporary and designed for competition at the pinnacle level of the sport.

247. VOR does not draw on the regulatory cover provided by World Sailing for the administration and conduct of the race and it may not be necessary to seek regulatory cover for the qualifications of PICs and navigators. The experience levels of the PICs and navigators are beyond reproach, especially operating in the heavily regulated VOR environment. The mariner certification could be provided by VOR.

248. There is not a neat match between what the RYA Yachtmaster 'Ocean' provides and the VOR PIC and navigator require. RYA training does not cover the specialised navigation systems, Expedition and Adrena. AIS and radar, and their application to collision avoidance, are not covered to the level of detail needed. Similarly, passage planning and the use of electronic charts are not covered to the level required for a VOR. The qualification adds little value to where it is required.

249. Race Management did raise the issue of using the RYA 'Coastal' course as a means of introducing young sailors into the event. The report team supports this as a way of transitioning a talented 'off the beach' or 'inshore' sailor to 'offshore'. The value of the course is, however, questioned when obtained retrospectively after having already competed in a VOR.

250. Moving forward there is always likely to be a gap between what the VOR requires, at the leading edge of the sport, and what RYA delivers for the commercial and recreational market. The people sailing as PICs and navigators in the VOR have superior skills and experience to the RYA 'Ocean' standard.

251. The PICs and navigators have nearly all of the knowledge and experience that they need for the race. VOR could assist in filling the small gap that is required for the fitted systems with which they are not familiar and, possibly, the specific route being sailed. This could be done through a few training sessions and workshops that would cover the fitted radar, AIS and navigation systems and their combined application in collision avoidance. Ideally the training sessions would be incorporated into the program during the pre-race assembly period. There is not a need and, it is not appropriate, to produce a complex course or qualification reverting back to basics.

252. The report team noted that some training was being conducted at Auckland in engine operation and maintenance as well as battery charging. This was possibly for the

benefit of new crew members who had joined the race after the pre-race assembly period or as a refresher. A similar package could be provided in AIS, radar and collision avoidance at appropriate stopovers if there is a need.

253. The report team considers that the block requirement for Yachtmaster qualifications be reviewed with respect to developing a more sophisticated requirement that recognises prior experience, the specific expertise needed and tailors the mandated certification accordingly. Furthermore the report team considers the assembly training package should be expanded to include training on the fitted radar, AIS and navigation systems and their combined application in collision avoidance. Refresher courses or workshops in these and other systems should be offered during the race if considered necessary.

Securité broadcasts through MRCCs

254. The VOR fleet sails 45,000nm racing round the world and passes through many areas where there is little knowledge of the race and the boats that compete. This lack of knowledge applies to the mariners that operate as fishermen, coastal traders, international shippers and recreational boaters, in areas that the fleet passes. These mariners operate in various regulatory systems and many monitor the VHF radio network or other means of communications used by the local MRCC or port authority.

255. A VO 65 is an unusual boat to many mariners. A sailing vessel capable of speeds of 20-30 knots and sailing in parts of the world where this type of vessel is not frequently encountered. The boat presents a challenging collision avoidance situation because of the high speed not normally associated with a sailing vessel and unfamiliarity with how it sails.

256. In preparing for the race, VOR consults with the MRCCs adjacent to the route and the stopover port authorities as a matter of course. In an attempt to provide greater awareness of the VOR among vessels operating in these areas the authorities should be requested to issue a Securité warning from the coastal radio station or harbour control when the fleet is approaching and transiting their respective areas.

257. The warning should be simple and advise when the boats are expected in the specific area, that they are sailing vessels capable of speeds of more than 20 knots and details of any distinctive lights that might be displayed. The warning would provide an alert to other mariners so that they would not be surprised by coming across a VO 65 in their waterway and better prepared to respond in accordance with IRPCAS.

258. One crew mentioned on the leg to Cape Town a message was received on Satcom C, warning of the presence of a single handed vessel *MACIF* sailing in the area as part of a record attempt round the world. While acknowledging that such warnings would not gain universal coverage of all vessels operating in an area, the crews and Race Management thought it could be helpful.

259. The report team considers that arrangements should be made with MRCC and stopover port authorities to issue local Securité warnings advising local mariners when the VOR fleet is in their area.

Finishing with a sail plan restriction

260. Crews provided information on two different scenarios - Hong Kong approaches and the Auckland Harbour finish. They are very different, one being congested open

water over 20nm from the coast and the other congested traffic within the close confines of a harbour.

261. Several ideas were put forward to minimise the risk of a collision. These included moving the finish away from the congestion, imposing restrictions such as sail selection from a nominated gate or imposing a speed limit from a nominated gate. These were discussed with the crews. The aims of these restrictions would be to either move the fleet clear of the problem area or to reduce the risk by slowing the boats down and improving the look-out with a reduced sail plan.

262. None of the options would work in the Hong Kong approaches as the distance is too far from the finish. In addition the fishing fleet is not static and the congested waters could be encountered as far as 100nm off the coast.

263. In Auckland the finish could be moved to the entrance of the harbour and resolve most problems. Also a restricted sail plan would achieve the aim of reducing the risk.

264. A speed limit, like a pit lane in a car race, was suggested within VOR Event Management, but is not considered practical. Although it could be monitored and policed technically, it would be difficult to sail the boat to such a restriction, especially in gusty wind conditions. All crews considered it counter-intuitive to racing, where you attempt to sail as fast as possible.

265. All crews did agree the finish in Auckland was risky and acknowledged the desire of Race Management to provide the finish close to the VOR Village and spectators. Race Management was also concerned that any restriction imposed would disadvantage the skilled boats and diminish the professionalism of the race.

266. Establishing a gate near the entrance to a finishing harbour has merit and was used by VOR at Gothenburg and The Hague in this race as the finish to legs 10 and 11. There were also similar plans in place for other ports. The report team also discussed with crews the idea of using a gate as a point to impose a sail restriction.

267. If a sail restriction was to be used it would be the same for all boats and not impact on the competition, although there might be a bit more than the normal compression experienced as the boats close the coast and enter harbour. The restriction would only be likely in high wind conditions and the difference to the spectators of whether a boat finishes with FRO instead of a MHO is unlikely to diminish the spectacle significantly.

268. Most crews were supportive of using a gate in some circumstances. The arrival at Auckland was fresh in their minds and it had been a stressful experience. There was not universal support, however, for a mandated reduction in sail. One comment was ‘don’t reduce sail coming into port, that’s going too far - enhance safety with better radar, briefings and all crew available on deck’

269. The report team supports the practice of establishing a gate off the port for use as the finishing line in some adverse conditions. The team suggests that to provide more flexibility and strive to achieve a finish close to the land based spectators, consideration be given to using the gate as a point to impose a sail restriction. Such a restriction might extend the window of conditions for the fleet to sail safely into the harbour to finish the leg.

Special temporary Traffic Separation Scheme

270. Another idea suggested by one crew and discussed with others was the establishment of a temporary form of a Traffic Separation Scheme (TSS) reserved for the VOR fleet. This was put forward in the context of the approaches to Hong Kong. The idea is not considered practical.

271. The idea can work at the start of a race where a port authority designates specific areas for spectators and an exclusive area for competitors. This requires considerable effort to mark and police the areas but it is for a short and clearly defined period that can be planned and communicated to local mariners well in advance.

272. TSS are established by the International Maritime Organisation and invoke IRPCAS Rule 10. Approval for a temporary scheme for the VOR would be unlikely. In the approaches to Hong Kong any local arrangement would involve mainland Chinese and Hong Kong jurisdictions and be problematic. Any such arrangement would be very difficult to promulgate to all vessels that operate in the area and to enforce. Similar issues are likely in the approaches of any major port.

273. A suggestion was also made to provide lead-in vessels to clear spectators or other vessels out of the way. This is also considered impractical in that it would require some special regulation in force to permit it to happen or direction from the Harbour Master or other authority. The difficulty of leading in a boat at over 20 knots, that is trying to sail tactically to finish the race is also considered to render the initiative impractical.

274. The report team does not consider that a dedicated traffic scheme or a lead-in boat should be contemplated any further.

Safe Speed

275. IRPCAS definition of ‘safe speed’ and the factors to be considered are listed at Section 4 and the discussion with crews on the subject is at Section 5.

276. ‘Proper look-out’ and ‘safe speed’ are closely linked in a form of three dimensional matrix. The better the look-out, the better your ability to determine the traffic density. If the traffic density is clear along and close to your course, the higher your safe speed unless negatively influenced by any of the environmental factors of visibility, background lights or a boat’s own back scatter of light, proximity of navigation dangers and depth of water.

277. The manoeuvrability of a vessel is also a factor to be considered but with a VO 65 this shall, in nearly all circumstances, be a positive. The boat is highly manoeuvrable, fully crewed by professional sailors, sails with a watch on deck with appropriate numbers for the prevailing circumstances and with eyes acclimatised to the dark at night. It could be a negative if the boat is being sailed right on the edge of control with the possibility of being over-powered and forced into an uncontrolled manoeuvre.

278. All else being equal a VO 65 could sail at its maximum speed of about 30 knots and this should be considered sailing at a ‘safe speed’; a theoretical speed for use in interpreting compliance with the regulations.

Figure 26 - A small boat on a large ocean - MAPFRE heading for Cape Horn on the rugged leg 7

Credit: Ago Fonolla/Volvo Ocean Race

279. The weak link in this chain is the look-out. Depending on the sails set the visual lookout on the lee bow could be restricted through about 90°. The radar performs poorly at detecting small contacts at a reasonable range. The AIS is a good aid but has been suffering reliability problems and degraded performance and is dependent upon the other vessel having an active AIS transponder.

280. The look-out is more of an issue in congested waters or any waters where there is a likelihood of some traffic. The problem diminishes in the Southern Ocean because there is unlikely to be traffic and any vessels in the area would have an active AIS transponder.

281. Any improvement in the 'look-out'- visual, AIS, radar and FLIR - will improve the robustness of the 'safe speed' assessment.

282. Among the many considerations of racing a boat round the world - the weather, the sails, the boat and the crew - the PIC must consider the 'safe speed' and realistically assess the quality of the look-out, the control of the vessel and the other environmental factors which may change at any time and impact the 'safe-speed'.

283. Fog, for example, would change the whole equation and crews acknowledged that they would slow down in such circumstances. Crews understand they have to 'finish to win' and the need to, at times, 'sail conservatively to preserve the boat'. These, however, are separate considerations to the IRPCAS 'safe speed'

284. The VO 65 is a robust boat and in the two editions of the VOR it has been used, it has been sailed harder and harder. Leg 7 of this edition indicates crews are sailing the boat close to its limits while, at most times, still sailing at a 'safe speed'.

285. The report team considers that all the recommended measures should be taken to improve the 'look-out' on the VO 65 and future boats used in the VOR, as well as the measures to enhance their visibility. These initiatives will assist the boats to race as fast as possible in such a demanding event, while still sailing at a 'safe speed'.

7. Recommendations

286. VOR boats racing round the world are very likely to come across areas of high vessel traffic density such as the fishing fleet in the approaches of Hong Kong. The crews, the boats and race administration are well positioned to meet this additional risk among the many others that are present in offshore trans-ocean racing.

287. The report team was asked to make findings and recommendations as to:

(i) any changes to the race administration, documentation and instructions or to the boats and equipment that might improve safety, and

(ii) any other matters relating to the conduct of the race that the team considers appropriate.

288. A Table of the findings and recommendations of the report is at Appendix 6.

289. This report is being presented following the finish of the 2017-18 edition of the VOR. The recommendations are made with a view to future editions of the race with the next generation of boats plus the expectation that the VO 65 will participate in the next edition.

290. Following the gathering of information from the crews, Race Management and others, the report team has analysed this data to make a number of findings. These have led to the following recommendations for VOR to consider:

Changes to Race

291. There are no major structural changes recommended for the administration of the race and its documentation. There are some enhancements proposed to improve the look-out from the VO 65 and enhance its visibility at sea, and in harbour. Both of these areas should positively impact the determination of a 'safe speed'. In support of this common goal to allow the boats to be raced as hard as practical, there are some minor changes recommended for the management of the race.

Possible Enhancements

Improved look-out

292. A proper look-out is a requirement of IRPCAS and a fundamental component in determining a safe speed. The better the look-out the faster the 'safe speed'. Conversely if you cannot look-out there is no 'safe speed'. VO 65's present a challenge in certain combinations of sail selection that are frequently used around the course.

293. The report team recommends that:

Visual look-out techniques

(paragraphs 151-157)

a. crews share information on the best techniques for maintaining a proper look-out with all combinations of sails that are likely to be used and restrict the look-out on the lee bow. These techniques would need to give careful consideration to ‘dipping the bow’ - by how much and how often - as well as the placing of a dedicated lookout when required by the prevailing circumstances. A workshop be considered to address the matter and exchange experiences.

AIS

(paragraphs 158-164)

b. the unserviceability and degraded performance of the AIS systems be further investigated. If testing proves that the antenna/coaxial cable system has degraded performance, the cable should be replaced. The BNC masthead antenna connector/mounting should be upgraded to a N-Type or TNC connector that is weather-resistant, physically rugged, and vibration proof. The loss of the coaxial cable should be checked at each stopover (a procedure is proposed at Appendix 5). The fleet’s AIS performance should be monitored as an end to end check of the complete system and this could be done by Race Control, Alicante using MarineTraffic.com.

c. a workshop or training program be provided to improve the level of operator expertise in the use of AIS for collision avoidance on the systems fitted in the VO 65. Feedback on the operator interface should be given to the navigation system providers Adrena and Expedition.

Radar

(paragraphs 165-168)

d. the existing FMCW radar be replaced with a pulse (or pulse compression) radar. Navigators should be offered training with the radar to obtain optimum performance from the system.

Forward looking infrared (FLIR)

(paragraphs 169-177)

e. VOR investigates and determines the practicality of installing a forward looking infrared camera in a location which provides an unimpeded look-out to assist collision avoidance and the recovery of a person overboard. VOR should use its position to strongly support and encourage the introduction of this technology to offshore racing. If available and deemed helpful, target enhancement software should be employed to draw attention to potentially dangerous objects.

Change sail plan

(paragraphs 182-185)

f. raising the clew of the large overlapping headsails has merit in improving look-out to leeward but notes its application to the VO 65 would depend on decisions regarding changing the rig or sail plan of the VO 65. With respect to any replacement design or a new class for the event, the report team recommends the issue of all-round visibility and the advantages of a bigger rig, less overlap and a raised clew should be seriously considered.

Enhanced visibility of the boat

294. While compliant with IRPCAS, the lighting of a VO 65 under sail does not provide much warning of the boat's presence. Noting the potential speed of the boats and the ineffectiveness of their navigation lighting, the report team considers the navigation lighting should be improved along with other measures to enhance the visibility of the VO 65 to other vessels.

295. The report team recommends that:

Navigation lights

(paragraphs 190-208)

a. VO 65s be fitted with a second set of sidelights and sternlight, near deck level, to enhance the presence of the boat at night in areas of high vessel traffic density and in harbour. The additional lights could be used, at the discretion of the PIC, in conjunction with the lights at the masthead, whenever warranted by the prevailing circumstances.

Masthead flashing light

(paragraphs 209-216)

b. an all-round white masthead flashing light be fitted to attract attention as an anti-collision warning light and used at the discretion of the PIC.

Illuminated mainsail

(paragraphs 217-222)

c a set of lights be installed on the upper spreaders to illuminate the top of the mainsail. Combined with the additional navigation lights and masthead flashing light, the PIC would have available a suite of measures to enhance the visibility of a VO 65 in a wide range of circumstances.

Race management

296. An apparent difference of opinion was noted between Race Management and the crews with regard to the value of briefings and provision of further guidance beyond the race rules and documentation.

297. The report team recommends that:

Sharing information

(paragraphs 227-238)

a. consideration be given to more comprehensive race briefings providing more information about the next leg and incorporating any matters wished to be raised by the crews.

b. a section on the digital noticeboard be used to place reports and other documents with lessons and guidelines that may assist crews in preparing for the VOR.

Training and Yachtmaster qualifications

(paragraphs 239-253)

c. the block requirement for Yachtmaster qualifications be reviewed with respect to developing a more sophisticated requirement that recognises prior experience, the specific expertise needed and tailors the mandated certification requirement accordingly.

d. the assembly training package be expanded to include training on the fitted radar, AIS and navigation systems and their combined application in collision avoidance. Further refresher courses or workshops in these and other systems be offered during the race if considered necessary.

Securité broadcasts through MRCCs

(paragraphs 254-259)

e. arrange for MRCC and stopover port authorities to issue local Securité broadcasts advising other mariners when the VOR fleet is in their area.

Finishing with a sail plan restriction

(paragraphs 260-269)

f. consideration be given to using a gate off a finishing port as a point to impose a sail restriction. Such a restriction might extend the window of conditions that the fleet could sail safely into the harbour to finish the leg near the land based spectators.

Safe speed

(paragraphs 275-285)

298. The report team recommends that all proposed measures be taken to improve the ‘look-out’ on the VO 65 and future boats used in the VOR, as well as the measures to enhance their visibility. These initiatives and additional training with critical systems will assist the boats to race as fast as possible in such a demanding event, while still sailing at a ‘safe speed’.

Appendices

1. Terms of Reference
2. Report Team - Short Resumes
3. List of Meetings, Interviews and Significant Email/Phone Exchanges
4. VO 65 - Main Technical Specifications and Sail Plan
5. AIS - Coaxial Cable Test Procedures
6. Table of Findings and Recommendations
7. List of Acronyms

Appendix 1 - Terms of Reference

TERMS OF REFERENCE – VOLVO OCEAN RACE REPORT INTO OCEAN RACING AT NIGHT IN AREAS OF HIGH VESSEL TRAFFIC DENSITY

Preamble

1. In recent editions of the Volvo Ocean Race the course has changed dramatically to visit many different parts of the world. This is in keeping with the global nature of the event, enhancing its commercial appeal as well as gaining greater international exposure for the sport.

2. As a result boats have sailed in some new and challenging waters - the coasts of India, Vietnam and China plus the Malacca and Singapore straits are examples. Some areas contain large numbers of small vessels mixed with commercial shipping. The situation becomes more complex at night noting the potential speed of the yachts and that some small vessels are often difficult to detect as they may not be lit, have a weak radar return and may not be carrying an active AIS[1] transponder.

3. The Volvo Ocean Race S.L.U. (VOR) has resolved to commission an Independent Report into how boats should operate in these congested waters to minimise the heightened risk and to provide further guidance to competitors. The report will be conducted on the basis of these Terms of Reference.

Constitution and administrative matters

4. VOR has invited Rear Admiral Chris Oxenbould AO RAN (Rtd) to Chair and invited Stan Honey and Chuck Hawley to assist. Together they will form the Independent Report Team (IRT).

5. VOR, through its President, Richard Brisius, is to provide secretariat and administrative support as required by the report team. The costs and expenses of the report will be borne by VOR.

6. The IRT will interview representatives from each boat currently competing in the race to obtain feedback of their contemporary experiences. These interviews are expected to be conducted during the race stopover in Auckland.

7. The IRT will meet at such times and in such places as the Chair shall determine in consultation with the VOR President. Sensible use of Skype, emails and teleconferences are to be employed.

Terms of Reference

8. The IRT is to provide its final report to VOR by 14 May 2018. A preliminary report may be provided if, after consultation with VOR, it is considered necessary to highlight any safety recommendations that may require immediate attention.

9. The IRT may seek input from crews on competing boats, members of the race committee, other relevant Organising Authorities and maritime regulators as well as such other persons as the team sees fit. The commissioning of the Report may be promulgated and written submissions from any interested party may be sought.

10. VOR will provide a report with any relevant data that is available from Race Control Headquarters at Alicante.

---

[1] AIS: Automatic Identification System

11. Those that provide oral or written submissions or comments to the IRT are to be advised that the findings and recommendations of the IRT and submissions received may be made public.

12. The IRT is to examine all the issues associated with racing a VOR 65, or near similar boat, at night in areas of high vessel traffic density, drawing on the experiences in recent editions of the VOR. In particular the IRT is to examine:

(i) general precautions that should be taken when racing in areas of high vessel traffic density,
(ii) best practice and technology to maintain a proper look-out as required by International Regulations[2],
(iii) managing the conflict between racing a boat at its maximum speed and sailing at a safe speed as required by International Regulations[3], and
(iv) the relevant administrative procedures and race documentation for the 2017-18 VOR.

13. The IRT is to make findings and recommendations as to:

(i) any changes to the race administration, documentation and instructions or to the boats and equipment that might improve safety, and
(iii) any other matters relating to the conduct of the race that the team considers appropriate.

14. VOR will accept a minority report.

15. VOR may from time to time provide additional terms of reference to the Report.

By direction of VOR
Richard Brisius
President

Antonio Bolaños
Managing Director

Volvo Ocean Race S.L.U.
Muelle nº 10
Puerto de Alicante
03001 Alicante
SPAIN

Chris Oxenbould AO
Rear Admiral RAN (Rtd)
Chair

23 February 2018

---

[2] International Regulations for Preventing Collisions at Sea 1972 (COLREGs) Rule 5

[3] International Regulations for Preventing Collisions at Sea 1972 (COLREGs) Rule 6

Appendix 2 - Report Team Short Resumes

Rear Admiral Chris Oxenbould AO RAN (Rtd)

Chris Oxenbould had a distinguished career of over 37 years in the Royal Australian Navy, in which he specialised as a navigator and gained substantial command experience. On retiring from the Navy in 1999 he worked with the New South Wales Government in positions including the Chief Executive of Newcastle Port Corporation 2001-04 and CEO of NSW Maritime, the state's maritime regulator, from 2004-08. Chris has been an active sailor for most of his life, competing in 10 Sydney to Hobart races and several seasons of offshore racing out of Sydney and a season in England. He was Chair of the Sydney Hobart Race Committee in 2000 and 2001, Chair of the Flinders Islet Inquiry in 2009 and the VOR Independent Report into the Stranding of Vestas Wind in 2015. He is a former Chair of Australian Sailings's National Safety Committee.

Stan Honey

As part of a career in navigation, digital mapping, and computer graphics, Honey led the development of the yellow first-down line widely used in the broadcast of American football, the "K-Zone" baseball pitch tracking and highlighting system, the tracking and highlighting system used in NASCAR, and the LiveLine system used in the 34th and 35th America's Cups. Honey has earned three Emmy's for technical innovation in sports broadcast.

Stan has wide experience as a professional navigator, having navigated ABN AMRO to first place in the 2005-2006 Volvo Ocean Race and having navigated Groupama 3 in setting the Jules Verne record for the fastest circumnavigation of the world in 2010. He has won line-honours or set records in all of the major oceanic passages and races. These efforts include 25 TransPacific races and 10 TransAtlantic races or record passages. Honey was awarded the 2010 US Sailing Yachtsman of the Year Award, and was named to the US National Sailing Hall of Fame in 2012.

Prior to co-founding Sportvision in 1998, Stan Honey worked as Executive VP Technology for News Corporation from 1993 through 1998. In 1983, Honey co-founded ETAK Inc., the company that pioneered vehicle navigation systems and digital street mapping which was sold to News Corporation in 1989 and is now part of TomTom. From 1978 to 1983 Honey worked as a research engineer at SRI International in the fields of Over-The-Horizon radar, underwater optical sensors, and radio positioning systems. Stan is an inventor on 8 patents in navigation and digital mapping technology and 21 patents in tracking and television special effects.

Chuck Hawley

Chuck Hawley is a lifelong sailor, having sailed extensively on boats ranging from ultralight 24 footers to the 125 foot catamaran PlayStation. He's competed in two Singlehanded TransPacific races, including a 2nd overall finish in his Olson 30.

He has applied the lessons learned from sailing across both the Atlantic and Pacific Oceans into hundreds of videos and articles on safety and seamanship. This knowledge has also led to the development of improved safety gear, technical clothing, anchors, and marine electronics for the boating industry.

Chuck is a nationally known speaker on marine safety, and Chair of the US Sailing Safety at Sea Committee for six years, a past member of the US Sailing Board of Directors, as well as being an Instructor Trainer for US Powerboating. During his work at US Sailing, he was instrumental in developing the Safety Equipment Requirements for racing sailboats in the U.S. that rapidly became the standard for U.S. offshore and coastal races. He also developed an online course Safety at Sea course, thus making the training more widely available in the U.S.

Chuck worked for West Marine for 30 years and held senior positions in marketing, merchandising, stores, and internet divisions. He is currently a product development consultant and develops technical and educational videos for marine industry. He lives in Santa Cruz, CA with his wife Susan and is a partner in an Alerion Express 38 Yawl.

Appendix 3 - List of Meetings, Interviews and Significant Email/Phone Exchanges

Date	Medium	Name	Representing/ Expertise
26-31 Jan 2018	Meetings	Richard Brisius - President Johan Salén - Co-President Antonio Bolaños - Managing Director	VOR
26 Jan 2018	Meeting	William Erkelens - COO	Vestas 11th Hour Racing
27 Jan 2018	Meeting	Phil Lawrence - Race Director	VOR
28 Jan 2018	Meeting	Jack Lloyd - VO 65 Compliance Officer	VOR
29 Jan 2018	Phone	Mr W.H.Wong - GM Vessel Traffic Services Branch	HK Marine Department
30 Jan18	Meeting	Inge Strompf-Jepsen - Former Commodore, Sailor, Race Officer Ailsa Angus - Sailing Manager Cameron Ferguson - Racing Navigator, RYA Sailing School Principal	Royal Hong Kong Yacht Club
12 Mar 2018	Interview	Charles Caudrelier - Skipper Pascal Bidegory - Navigator	DONGFENG RACE TEAM
12 Mar 2018	Interview	Simeon Tienpont - Skipper Jules Salter - Navigator Chris Nicholson - Watch Captain	AKZONOBEL
13 Mar 2018	Interview	Nick Bice - VOR Chief Technical Development Officer Dan Jowett - Electronics Team Leader Alan Davis - Navico Radar Liam Wildish - Diverse Yacht Services	VOR - Boatyard
13 Mar 2018	Interview	Bouwe Bekking - Skipper Andrew Cape - Navigator	TEAM BRUNEL

13 Mar 2018	Interview	Phil,Lawrence - Race Director Jack Lloyd - VO 65 Compliance Officer	VOR - Race Management
13 Mar 2018	Interview	Xabi Fernandez - Skipper Joan Vila - Navigator	MAPFRE
14 Mar18	Phone Interview	Cameron Ferguson - Asia Pacific Yachting	RHKYC RYA
14 Mar 2018	Interview	Dee Caffari - Skipper Brian Thompson - Navigator	TURN THE TIDE ON PLASTIC
14 Mar 2018	Interview	Brad Jackson	VOR Competitor
14 Mar 2018	Interview	Torben Grael	VOR Competitor
14 Mar 2018	Phone Interview/ Emails	Sir Robin Knox Johnston	Clipper Round the World Yacht Race
15 Mar 2018	Phone Interview	Gonzalo Infante - Race Control and Meteorology Manager	VOR - Race Control
15 Mar 2018	Meeting*	Chris Aitkins	VOR International Jury
15 Mar 2018	Interview	Charlie Enright - Skipper Simon Fisher - Navigator Tony Mutter - Watch Captain	VESTAS 11th HOUR RACING
15 Mar 2018	Interview	David Witt - Skipper Libby Greenhalgh - Navigator	SUN HUNG KAI/ SCALLYWAG
15 Mar 2018	Meeting*	Johan Salén - Co-President	VOR
18 Mar 2018	Phone/ Emails	Ken Read - President	North Sails Group

4 Apr 2018	Phone	Alan Davis - Product Line Director of BandG Lindsay Liburn - Navico Systems Engineer for Radar Systems Andrew Corbett - Navico Chief Technical Officer	Navico
6 Apr 2018	Meeting	Jay Robinson, Vice President, Product Management Marcel Tremblay, Director of Mechanical Engineering	FLIR Maritime and FLIR Systems
April 2018	Multiple Emails	Jack Lloyd - VO 65 Compliance Officer	VOR - Race Management
April/May 2018	Phone/ Emails	Nick White	Expedition Navigation Software
24 Apr 2018	Phone	David Lyons	Naval Architect - Navigation Lights
April 2018	Multiple Emails	Cameron Ferguson	RYA Sailing School Principal, Hong Kong
April/May 2018	Email	Cécile Rodet - CEO	Adrena Navigation Software

Notes:

1. Interviews were conducted with all three members of the Report Team present.
2. Meetings usually took place with a single member of the Report Team - at Meetings marked with an * all report team members were present.
3. Phone calls, excluding phone interviews, were individual calls with a single member of the Report Team.
4. Emails were shared with all Report Team members.

Appendix 4 - VO 65 - Main Technical Specifications

VO 65 - Main technical specifications

The technical specifications for the boat are developed in conjunction with suppliers and the designers and full details can be found in the Volvo Ocean 65 Class Rules located in the race Noticeboard.

Hull Length (ISO 8666)	20.37 m (66 ft)
Length waterline (design)	20.00 m (65 ft)
Length overall (inc. bowsprit)	22.14 m (72ft)
Hull Beam overall (ISO 8666)	5.60 m (18.4 ft)
Max Draft (Keel on CL)	4.78 m (15.8 ft)
Boat Weight (empty)	12,500 kg (27,557 lb)
Keel arrangement	Canting keel to +/- 40 degrees with 5 degrees of incline axis
Daggerboards	Twin forward daggerboards, inboard triangulation
Rudders	Twin fixed rudders - composite stocks
Aft Water Ballast (Wing Tanks)	Twin 800L ballast tanks under cockpit sides at transom
Forward Water Ballast (CL)	Single centerline 1100L ballast tank forward of mast
Rig Height	30.30 m (99.4 ft)
Rig Arrangement	Twin topmast backstays and checkstays with deflectors
Bowsprit Length	2.14 m (7ft)
Mainsail Area	163 m2
Working Jib Area	133 m2
Upwind Sail Area	468 m2 (mainsail and masthead Code 0) 296 m2 (mainsail and working jib)
Downwind Sail Area	578 m2 (mainsail and A3)

Appendix 5 - AIS Coaxial Cable Test Procedures

Coax Testing for Marine VHF and AIS

Stan Honey

The loss in RF coaxial cable increases substantially, and quickly, when there is water intrusion. Coax that uses foam dielectrics, like RG8X and LMR type coax, is particularly prone to this problem because the water can quickly propagate along the foam dielectric used in these type coaxes. Simply measuring SWR from the base of the mast is not able to detect lossy coax because the increased attenuation due to lossy coax is indistinguishable from a well matched antenna.

A relatively convenient solution is to disconnect the antenna at the masthead and then measure the "return loss" which is the amount of RF power reflecting back down the coax from the open end. Because the top of the coax is disconnected there will be 100 percent reflection, so the coax loss is half the measured return loss. This test requires the use of a directional power meter or SWR meter.

Test Equipment

Obtain the following test equipment, or equivalent.

- Bird 43 power meter
- Bird 25C "slug" for the above power meter
- VHF radio, 25 watt, for test
- Coax connectors for interconnecting the radio to the Bird meter, to the coax.
- 25 watt (or more), 50 ohm, dummy load for use for testing coax on the bench, or for testing short coax lengths.

Test Procedures

Common Sense Test procedure with coax in place in the mast

1. Disconnect the antenna at the masthead
2. Connect the VHF radio to the Bird meter, and the other port of the Bird meter to the end of the coax that connects from the mast to the AIS splitter.
3. Measure the forward power (from the radio to the coax)
4. Rotate the Bird meter slug and measure the reflected power (from the coax back to the radio)
5. The reflected power should be greater than 36% of the forward power.
    a. For example if the forward power is 25 watts, the reflected power should be greater than 9 watts, which is 0.36*25
    b. Explanation: the OSR's require a maximum power loss of 40%, which is a minimum power transmission of 60%. The reflected power is passing though the coax twice, up and down, so that would be a minimum power transmission of 60% up and 60% return, which is 36%.
6. Finally, to test the antenna, reconnect the antenna at the mast head. Again measure the reflected power at the boat end of the coax. The reflected power

should now be less than 1 watt (which is a SWR of 1.5 or less) if the antenna is good. If the reflected power is still 9 watts, then the antenna is open or shorted.

If your meter only reads SWR, and not directional power:

1. If the SWR is >4.0 with the antenna disconnected, then coax loss is acceptable (i.e. less than 2.2 dB loss).
2. With the antenna reconnected, if he SWR is < 1.5 then the antenna is ok.

Technical Version of Test procedure for RF engineers and technicians

1. Disconnect the antenna at the masthead.
2. Connect the VHF radio to the Bird meter, and the other port of the Bird meter to end of the coax that connects from the mast to the AIS splitter.
3. Measure the forward power (from the radio to the coax)
4. Rotate the Bird meter slug and measure the reflected power (from the coax back to the radio)
5. Compute the coax loss in dB as 5* (log (P(fwd)/P(ref)))
7. Compare the measured coax loss to the cable specifications and to the requirements. The coax must have less than the OSR maximum 2.2 dB (i.e. 40%) power loss.
8. Finally, to test the antenna, reconnect the antenna at the mast head. Again measure the reflected power at the boat end of the coax. Compute the SWR from the nomographs that come with the Bird Meter. The SWR should be 1.5 or lower. A higher SWR indicates that the antenna is open or shorted.

Bench test for coax.

1. The return loss approach to testing coax above works great for long lengths of coax, e.g. for coax in the mast where it would be inconvenient to operate a power meter at the masthead. For short lengths of coax the return loss may be low enough so that the VHF radio will not transmit into such a high mismatch. To test shorter lengths of coax on a bench use the following approach.
2. Connect the VHF radio to the Bird Meter, and the other end of the Bird Meter to the coax.
3. Connect the dummy load to the far end of the coax.
4. Measure the forward power from the VHF radio to the coax.
   a. Note the reflected power. If there is any measurable reflected power it indicates a bad connection or flaw in the coax
5. Move the Bird Meter to the far end of the coax, between the coax and the dummy load.
6. Measure the forward power from the coax to the dummy load.
7. Compute the coax loss in dB as 10* (log (P(radio)/P(load)))
8. Note that Losses for some common types of coax, in dB per meter, are:
   a. LMR600 0.0324 dB/m
   b. LMR400 0.0516 dB/m

c. RG8 or RG213 0.0818 dB/m

d. LMR240 0.1012 dB/m

e. RG8X 0.1525 dB/m

f. RG58 0.1889 dB/m

9. Comparison between the measured loss and the theoretical loss will indicate coax that has suffered from a wet dielectric. Note that at VHF frequencies the loss due to properly installed coax connectors is immeasurably low. The coax losses above are for 156.8 MHz, in the marine band.

Recommended Installation Practice for RF cables in a marine environment:

- If a coax connector is used in a wet environment, fill the interior of the coax connector with silicone dielectric grease (e.g. Dow Corning 4 but there are lots of equivalents). With no air cavities in the coax connector, there is no place for water to go. The silicone grease adds zero RF loss at any frequency below 1 GHz but adds enormous immunity to water intrusion and corrosion.
- Use water-resistant coax connectors such as Type N or TNC. PL259 (aka "UHF") and BNC connectors are not weather proof and so are less dependable in a marine environment.
- If an antenna is physically mounted using a coax connector, do not use a "quick-connect" connector such as a BNC where the shell is held by springs and does not provide strong and vibration-resistant mechanical support for the contacts and antenna.
- Wrap the connector tightly with self-amalgamating tape (e.g. Scotch 2228) for water protection, and then again with vinyl electrical tape (e.g. Scotch 33+) for mechanical protection.
- Test the coax loss periodically to detect water intrusion.

Interference from LED lights at the masthead:

A few older design masthead LED lights (e.g. running or anchor lights) emit noise in the marine VHF band from their switching circuitry. A quick way to test for this is to tune your VHF radio to an unused channel, turn the squelch all the way down so that you can hear the receiver noise, and then turn the masthead lights on and off to see if you can hear them.

Another test that works in a coastal area with lots of AIS contacts is to run your AIS transponder for 10 minutes, and develop an impression of how many AIS contacts there are, and how far the most distant ones are. Then turn on the masthead LED lights, run the AIS transponder for the same period of time, and compare the results.

Most currently available masthead LED lights are sufficiently well-designed to emit no interference, or just barely noticeable interference, in the marine VHF band. It is worth testing however. Some early and poorly designed masthead LED lights would nearly deafen a VHF or AIS due to emitting strong RF interference.

Appendix 6 - Table of Findings and Recommendations

Summary Table of Findings and Recommendations of the Volvo Ocean Race Independent Report

Into Ocean Racing at Night in Areas of High Vessel Traffic Density

Category	Finding/Recommendation	Pros	Cons	Team Decision
Improved Look-out				
Visual techniques	- share information - 'dipping the bow' - dedicated look-outs - conduct workshop	- flexible look-out adapted to the prevailing circumstances - meets IRPCAS requirement	- 'dipping' will slow the boat - extra lookouts will place pressure on crew resources	Yes
AIS	- investigate degraded performance - replace antenna connector - improve watertightness of fittings - check cable loss at each stopover - monitor system performance - training program for operators - feedback to Expedition and Adrena	- better reliability and performance from a very important look-out sensor - more competent operators - improving systems	- an additional maintenance task for each stopover	Yes
Radar	- replace FMCW radar - training for navigators on new radar	- a radar that will provide an important input to the look-out - more competent operators	- cost	Yes
FLIR	- investigate feasibility of installation - strongly support and encourage adaption of technology for offshore racing	- potential for a great aid to assist the look-out - VOR contribution to sailing	- cost	Yes
Sails - clear panels	- place clear panels in the foot of MHO and FRO - leave a triangle at foot of sail unpainted	- possibly a better look-out	- significantly reduced life of sails - unpainted section of sails unlikely to work	No

Category	Finding/Recommendation	Pros	Cons	Team Decision
Change sail plan	- shorten the luff perpendicular (LP) and raise the clew of MHO, FRO and A3	- Would work and improve look-out	- very expensive to retrofit to VO 65 - should be considered for replacement boats	No/Yes
Enhanced Visibility of a VO 65				
Navigation lights	- fit a second set of sidelights and an sternlight near deck level - Could be used in conjunction with existing sidelights and sternlight at the masthead	- enhanced presence, important in harbour - better compliance with IRPCAS as a power driven vessel		Yes
Masthead flashing light	- fit an all-round white masthead flashing light to attract attention as an anti-collision warning light	- significantly enhanced presence - provides an anti-collision warning		Yes
Illuminated mainsail	- fit a set of lights on the upper spreaders to illuminate the top of the mainsail - All 3 additional light options would be available for use at the discretion of the PIC, either individually or in combination	- enhanced presence, well suited for harbour - assists other vessels in estimating range		Yes
Securité broadcasts from boats	- individual boats broadcast a Securité warning when passing through congested waters on VHF Ch 16 - Already available to boats if there is considered to be a need	- could provide warning to other boats in a HVTD areas	- ability to use local language and working frequency	No

Category	Finding/Recommendation	Pros	Cons	Team Decision
Race Management				
Sharing information	- race briefings to be more comprehensive and informative, incorporating matters wished raised by crews - add a section to the Digital Noticeboard to place reports and other documents with lessons learnt and guidelines to assist crews	- meet the stated requirement of crews - share experience within the fleet	- more pressures on an already tight schedule but could be accommodated in plans for future editions	Yes
Training and Yachtmaster qualifications	- review the block requirement for Yachtmaster qualifications - develop a more sophisticated requirement that recognises prior experience - provide safety workshops/ training sessions on specific safety issues and fitted systems - tailor the mandated requirements to match the needed expertise in onboard systems and electronics	- a better match of training and qualifications to what is needed for the VOR - specific training or workshops targeted at fitted equipments - radar, AIS, Nav systems etc.	- VOR will need to develop a training program but if focussed on fitted electronics, systems and the selected route it would be limited in its scope	Yes
Securité broadcasts from MRCCs	- arrange for MRCC and Stopover port authorities to issue local Securité warnings when VOR boats are in their area	- provides advanced warning of the VOR fleet - a sensible warning and collision avoidance measure	- an extra task for VOR to coordinate	Yes
Finishing with a sail plan restriction	- consider using a gate near the entrance to a stopover port in specific conditions to be used to impose a sail restriction - for use sparingly in extreme conditions	- provides more flexibility for the Race Director for extreme conditions - may extend the window of conditions that the fleet could sail safely into harbour to finish	- not universally accepted by the crews and seen as a challenge to their professionalism	Yes

Category	Finding/Recommendation	Pros	Cons	Team Decision
Special temporary TSS	- a temporary Traffic Separation Scheme or a lead-in vessel be considered for each finish	- possible protection of the fleet to reduce risk of collision in congested areas	- considered to be impractical	No
Safe Speed				
Safe speed	- the proposed measures for improving the look-out and enhance the visibility of the VOR fleet be implemented - the initiatives will assist in keeping the high speeds attained by boats complying as a 'safe speed'	- clear demonstration of commitment to IRPCAS - good seamanship and race management		Yes

Appendix 7 - List of Acronyms

List of Acronyms

A3	A Gennaker downwind sail (375m^2)
AIS	Automatic Identification System – based on VHF radio system
B&G	Brookes and Gatehouse (electronics and navigation systems)
cm	centimetres
CPA	Closest Point of Approach
ECS	Electronic Chart System
ENC	Electronic Navigation Chart
ERS	Equipment Rules of Sailing
FLIR	Forward Looking Infrared
FMCW	Frequency Modulated Continuous Wave
FR0	Fractional Code Zero sail (235m^2)
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
IHO	International Hydrographic Office
IMO	International Maritime Organisation
IMOCA	International Monohull Open Class Association
IR	Infrared
IRPCAS	International Regulations for Preventing Collisions at Sea
J0, J1, J2 and J3	Jib sails Numbers 0(171m^2), 1(132m^2), 2(87m^2) and 3(45m^2)
knots	nautical miles per hour (1.852 kilometres per hour)
kW	Kilowatts (1,000 watts)
LED	Light Emitting Diodes
LP	Luff Perpendicular
m	metres
m^2	square metres
MCA	Maritime and Coastguard Agency (UK Maritime Regulator)
MFD	Multi Functional Display

MH0	Masthead Code Zero sail (305m^2)
mm	millimetres
MMSI	Maritime Mobile Service Identity
MRCC(s)	Marine Rescue Coordination Centre(s)
nm	nautical mile (1,852 metres)
NOR	Notice of Race
OA	Organising Authority - VOR
OSR	Offshore Special Regulations
PDF	Portable Document Format
PIC	Person in Charge (Colloquially ‘the skipper’)
RCS	Radar Cross-Section
RRS	Racing Rules of Sailing
RYA	Royal Yachting Association
SAT C	Satellite Communications - text only telex via Inmarsat L-Band
SI	Sailing Instructions
TWA	True Wind Angle
VCA	Volvo Ocean 65 Class Authority
VHF	Very High Frequency
VO 65	Volvo Ocean 65 class of boat used in the 2014-15 and 2017-18 editions
VO 70	Volvo Open 70 class of boat used 2005-2012 for 3 race editions
VOR	Volvo Ocean Race S.L.U.