International Offshore Rule:

Influence on S&S Swans
And a Brief Overview of the Evolution of Handicap Systems
(In Pursuit of the Holy Grail)

*By Jim Teeters & Alan Gilbert**

Basics

The history of rating and handicapping sailboats goes back almost 200 years. As soon as two dissimilar boats raced each other, attempts were made to determine which yacht won. The approach used was to measure what was perceived as the critical speed producing characteristics of a yacht and plug these numbers into an algorithm. That algorithm calculated the inherent speed of each of the two yachts in the form of a rating, typically expressed in units of length such as feet or meters. The rating difference would be converted into a time allowance given to the slower yacht. This time allowance reduced the slower boats elapsed time to what is termed "corrected" time. The boat with the faster (smaller) corrected time would be the winner.

There are several elements to this process. The following definitions and explanations should be helpful in understanding this article:

- Measurement – The set of procedures for measuring the yacht to quantify those characteristics that determine speed. Typical measurements have included the boat's length, displacement (weight), draft, sail area. These are then the inputs to the rating rule.
- Rating Rule – The set of formulas that balances the various inputs, does so in a logical manner that reflects the performance of a sailboat, and arrives at a number, referred to as the rating.
- Scoring – A time allowance, based on the rating, is applied to determine how much time a higher rated yacht gives to a smaller rated yacht, to compensate for the difference in their potential speed.

Rating Rules

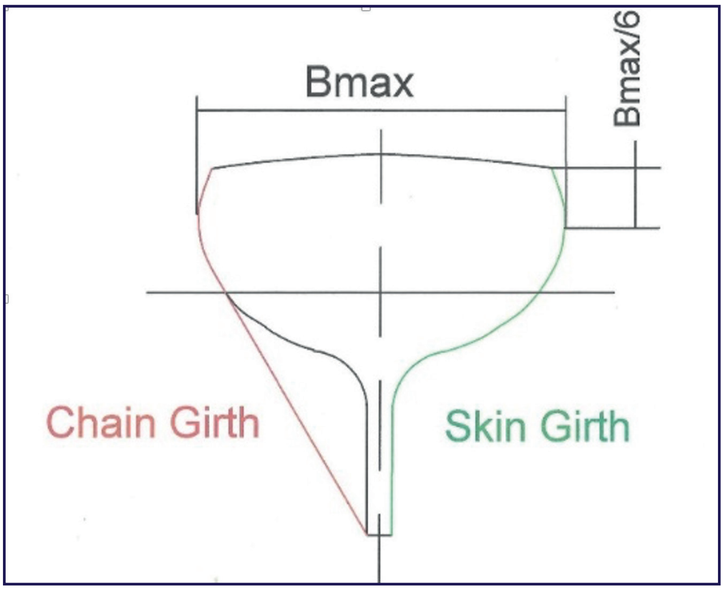
Once the rule is published, designers will develop new designs with that rule in mind. They may choose some innovative concept that advances the sport, or they may try to "beat the rule". There is a fine line between "beating a rule" and being innovative. The authors leave it to the reader to make that judgement on a case-by-case basis. As for example, the earliest rules did not consider some of the now obvious characteristics, such as weight, that today we would feel have quite a significant effect on speed. Rating rules can also encourage distortions. The Herreshoff Universal Rule of 1902 did not measure the length overall (LOA) but the length on the waterline (LWL), which resulted in boats tending to have short LWLs and long overhangs. The result was that the Rule rated the boat slower than it actually was. If any of these types of design trends/distortions were considered undesirable, the rule would be modified, or another rule written to take its' place. In doing so, the rule makers could preserve the competitiveness of the existing fleet and encourage what they deemed "good" design. The result was a never ending back and forth between yacht designers and rule makers as each party pursued their role in the handicap game: one to create fair racing between dissimilar boats, the other to design boats that gained a competitive advantage either by being faster or fooling the rule into predicting they were slower than they in reality were.

In response to the creative approach taken by designers, and the growing knowledge of what made boats fast or slow, each subsequent rule required more measurements and more complicated formulae. An outstanding example of this is the International Offshore Rule (IOR). The IOR contains about 270 variables, each used in some formulation to predict speed or to prevent "bad" design. Many of the measurements and formulas were, in effect, the equivalent of bandages that were placed as needed to cover flaws in the rule. The complexity of the IOR led to a new innovation: the use of computers for the computation of ratings.

Rules, a Historical Perspective

The following is a simplified summary of some of the rules and their characteristics that have been developed, ever since the first yacht challenged another for the "bragging rights" of being faster. (It should be noted that some of these rules are specific to a geographic area, hence some may not be familiar to the reader.)

- Tonnage Rule, circa 1830's, measured length, beam, and depth. This "rule" was originally in place to measure the volume of cargo, to determine the value of the cargo that a vessel could carry, to calculate import/export fees. Obviously, this was a "bare bones" rule.
- The Seawanhaka Rule of the late 19th into early 20th centuries, measured only length and sail area. Both of those are parameters that, when larger, make a boat faster. A huge influence on speed, the weight (displacement) of the boat, was not included in this rule.
- The Universal Rule, created by Nathaniel Herreshoff, 1902 and still in limited use, included displacement; the greater the displacement the slower the boat was predicted to be if the other terms, sail area and length, remain constant. As noted above, in order to look "slow" to the Rule, these boats would pick the desired waterline for the length measurement and then have enormously long bow and stern overhangs which would increase the actual sailing waterline length when the boat was sailing at moderate to high speeds. As the draft of the boats was not measured rule beaters would have deep drafts for better, unrated, speed upwind. Also missing was the beam of the boat which can contribute to form stability, although higher beam contributes to more wetted area and more



Girth & Bmax Illustration 1

friction drag. This rule is the basis for the alphabetic classifications of the S, R, Q, P, M, L and J classes.

• The International Rule, 1906 Europe, was created by an international collaboration. The terms that comprise the equation of the rule include LWL, beam, chain girth, difference between skin girth and chain girth, sail area, and freeboard. (*Refer to the Girth & Bmax Illustration 1 above*).

Over the years this Rule has been changed three times. Counter to the trend that newer rules become more complicated, today's International Rule's equation dropped a few variables from the original version. And some of the multipliers and constants changed. This rule gave rise to the well-known metre boat classes, such as the 5, 6, 7, 8, 10 and the 12 which for many post-war years was used for the America's Cup competition. It should be noted that the rule "metre" is not a measure of length but rather the result of an equation.

• The RORC & CCA Rules dominated racing from 1964 to 1980. The RORC (Royal Ocean Racing Club) rating rule was primarily used in England and other European countries, while the CCA (Cruising Club of America) rating rule was primarily in the United States. With the increase in popularity of offshore racing, and an increase in the number of yachts crossing oceans to race, it became apparent that a unified rule was needed. In short, yacht racing was becoming a serious and popular international sport.

• The IOR (International Offshore Rule) was developed in the mid 1960's. It merged the strengths of each of the "parent" rules, RORC and CCA. The RORC was the basis for the hull measurements, with some adjustments. The CCA Rule was the basis for the sail measurements, with some adjustments. As mentioned at the beginning of the Rules section of this article, once a rule is promulgated designers/sailmakers seek ways to reduce the ratings of their boats. The S&S Swans were no exception. For S&S the Swan design process was a balance of creating on one hand a sensible, esthetically pleasing shape and on the other a design that, through hull distortion, "looked slower" to the IOR than it actually was. This was a balance of the art of design and the art of beating a rule.

• Post 1980s – The IOR Rule began to fall out of favor, and this spawned several new Rules:

MHS – Measurement Handicap System which became in 1987:

IMS – International Measurement System

PHRF – Performance Handicap Rating Formula.

Many of these took a totally different approach to solving the question of how fast is a yacht. But they shared a common goal of determining the relative speed between two yachts. As this article is intended to discuss the influence of the IOR on the S&S Swans, for the sake of brevity, further details of the post IOR era are included only as comments at the end of this article. It is however worth noting that both MHS/IMS and PHRF took entirely different approaches to measurement and rating. MHS was the first rule to completely measure the entire boat and to use a set of formulas (velocity prediction program) that explicitly replicate the physics of sailboat performance. PHRF, on the other hand, has no formulas, and is entirely empirical, meaning ratings are based on observation of actual performance.

Time Allowance

A rule authority creates a formula that provides time allowances between boats based on their rating. The purpose of the time allowance is to give the slower boats more time to finish the course compared the faster boats. There are two types of time allowances, as follows:

• TOD (Time On Distance): Time allowances are expressed as sec/mile owed to each boat by a chosen reference (scratch) boat. (If the scratch boat is not the fastest boat in a fleet, the faster boats will have negative allowances.) The corrected time, with which a boat is scored, is that boat's elapsed time adjusted by the product of the sec/mile allowance and the length of the course. The length is the sum of the straight line distances (as the crow flies) for all legs of the race. Boats slower than the scratch boat get their elapsed time reduced, those faster get it increased. Note that TOD says that the sec/mile owed is invariant with wind speed or course layout unless, of course, a rating system provides for more than one TOD rating. In fact, modern velocity prediction program (VPP) rules generally offer an array of ratings specific to various combinations of wind speed and course content. However, in a single number rule boat A will always owe boat B the same amount of time per mile.

- TOT (Time On Time). The time allowances between boats are expressed as ratios or percentages, for example boat A owes boat B 10%. This means that boat A is predicted to be 10% faster through the water. By definition, the scratch boat rating is 1.000 because it owes itself 0%. A boat that is 10% faster would have a rating of 1.100, one that is 10% slower a rating of .900. To score a race you simply multiply each boat's elapsed time by its rating. Again, a particular rating system may have only one TOT rating or, in the case of a VPP rule, multiple ones tuned to specific conditions. A TOT rating is commonly termed a Time Correction Factor (TCF).

Which is better, TOD or TOT? That answer depends on both the nature of the race and the expectations and experience of the competitors. If the TOD and TOT ratings are derived from the same course conditions and speed predictions, then they will give identical results when a race is run in those same conditions. When the real weather is different, then the two methods give different results. Typically as the wind gets lighter, the performances of boats in sec/mile spread apart, and as the wind gets heavier they converge (if we set aside the fact that some boat types may plane sailing downwind.) But TOD says the time allowances are constant. Therefore, with a single number TOD rule, the faster boats are favored in light conditions, the slower ones favored when the wind is heavy. The assumption behind TOT however, a constant ratio of performance, scales up and down the wind speed more accurately and provides fairer racing.

From the competitor's side it is easier to track your performance on the water with TOD. Sailors usually know the length of each leg of the race and can multiply that by the sec/mile allowances. Since they also observe the time differences at each mark, it is easy to calculate this in your head and know how your boat is doing relative to others. With TOT you only need to know the elapsed time at marks but to multiply that time by a rating expressed to 2 or 3 decimals requires a hand held calculator for most of us. (Note that TOT does not require knowledge of race distance, a plus.)
Recent experience in the US is the broader use of single number TOT to better cope with changes in wind speed. It is the opinion of the authors that sailors are embracing a slightly more complicated way to track how they are doing in the interests of greater fairness.

Influence of the RORC/IOR Rules on the S&S Swans

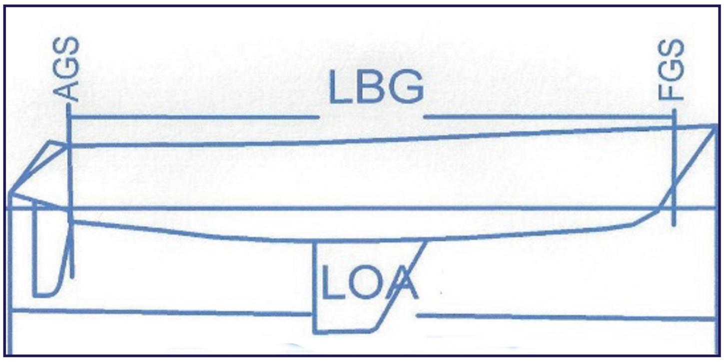
S&S's involvement with the Swan line of yachts spanned from 1965 to 1978, which is essentially the same period the IOR flourished.

While we are all familiar with the features of an IOR designed yacht, hopefully the following explanations will give the reader some insights into how and why they came about. While many of these features resulted in a slower boat, the rule "believed" they made the boat even slower than reality. For this reason much of IOR design pursued otherwise undesirable trends simply because there was a gain to be made in rated versus actual speed.

A list of some of these features, which have been exploited to a lesser or greater extent, follows:

• Tumblehome – Under IOR, the Rated Length (L), maximum beam (Bmax), and longitudinal location of the four girth stations are interrelated. L is defined as the length between girth stations (LBG), plus small corrections forward and aft. The girth station locations are determined where the girth at a section equals a percentage of the Bmax. As the fore and aft location of the girth stations are a function of the Bmax, the larger the Bmax, the larger the required girth measurements. Thus, an increase in Bmax moves the after girths forward and the forward girths aft, until each of the fore and aft sections are equal to the required girths. As rated length equals LBG plus some small adjustments, the rule "sees" a shorter yacht.
The Rule requires that the Bmax measurement be taken at 1/6 x Bmax below the sheer. (Refer to Girth & Bmax, Illustration 1) So, to maximize this measurement, the beam at the measurement point is substantially increased creating a "bubble", and another benefit to the rating.

• Displacement and wetted Surface –The speed potential of a yacht, for a given length, is limited by the drag created when "pushing" through water. The predominant two drag factors are displacement (weight), and wetted surface (WS). At high speeds weight has a much greater influence on speed than WS. But the reverse is true at slow speeds. As the rule does not explicitly measure either of them, it results in a strong impetus to minimize them. This was achieved by making boats "smaller" with less volume and less wetted area in areas between measurement points. The principal hull areas of measurement were forward, aft and amidships. In between those areas the hull volume and wetted area were minimized. The optimization result was the creation of "diamond" shaped designs: big in the middle to get rating credit for beam, then straight lines to forward and aft measurement stations as shown in Bubble/Pinched Ends Photo 1 (below). These hull shapes, when heeled over, tended to lift out of the water, exposing the top of the rudder and making the boats much harder to control when pressed off wind.



LBG Illustration 2

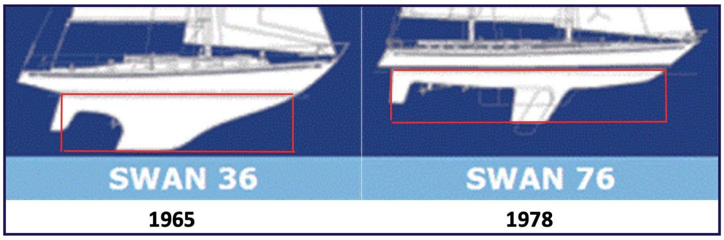
***(Refer to LBG Illustration Above)* One basic hydrodynamic principle is, the longer the length the greater the speed potential. The rule rewarded boats that pushed out Bmax, even if this resulted in distorted hull shapes, by under-predicting the effective sailing length and with it the yacht's speed. What does this have to do with tumblehome?**

• Appendage Area--Reducing the wetted areas of keel and rudder would also reduce drag but limit their ability to create the lift required to sail on the wind as a counterbalance to the sail side force. Insufficient foil area requires the boat to then sail at wider angles and faster

Bubble/Pinched Ends Photo 1

boat speeds. This generally results in a loss of Velocity Made Good (VMG) speed upwind and certainly limits the ability to point at high angles, a feature so important in fleet racing around the buoys, especially at the start. Ultimately then there was little reason to reduce those areas.

- Appendage location--Most of the IOR yachts have a cutaway forebody and separate rudder, with or without a skeg. This results in more distinct appendages, as opposed to them being blended into the hull. By separating and moving the rudder aft, the increased lever arm of the rudder created a greater turning moment which then permitted using a smaller rudder than if attached to the keel. The trend to reduce rudder WS can best be illustrated by comparing the underbody of the 1965 Swan 36 with the 1978 Swan 76.



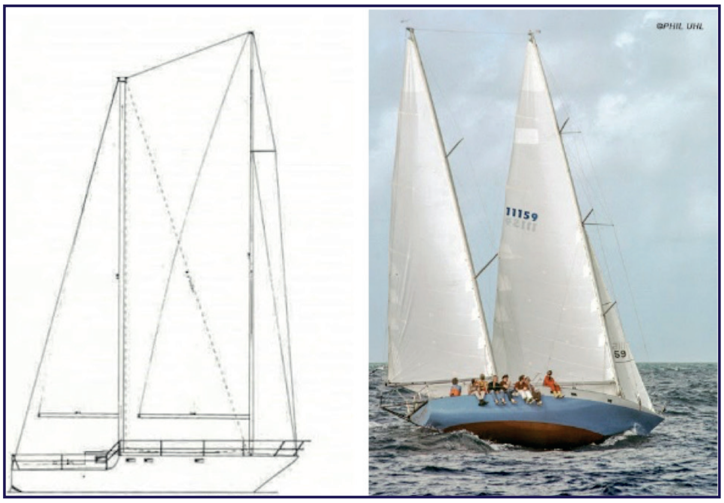
Note the percentage of area that the hull and appendages occupy in the rectangle formed by the length of the LWL by the draft

- Reverse Transoms – The intersection of the deck edge and the transom defined the locations of the after-girth stations (AGS). Moving that intersection forward resulted in an apparently shorter boat. To maintain a stern that extended aft of the girth stations, the IOR designs had reversed transoms. The effect on rating was similar to that of the Bmax/tumblehome explanation: a shortened LBG. In addition, there is a small reduction in weight by eliminating some aft deck area.
- Stern Bustle –In assessing a yacht's effective sailing length, IOR included the effect of the profile slope of the hull at the after girth station. In fact there were two

The photo below illustrates the extreme distortion of the IOR stern bustle in creating a steep implied stern slope, just forward of the rudder. Distortions like this were typical of IOR and, while the boat was slower for its overall length than an undistorted shape, the IOR predicted the boat even slower than that, thereby encouraging distortion.

aft stations at which girths and vertical heights of the hull were taken. The greater the vertical separation of those two heights, the greater the "implied" slope of the stern overhang. At moderate to high boat speeds a steep stern overhang is slower than a more horizontal one, the latter creating an effectively longer boat. Pinching the boat at the aft stations created what we term the stern bustle.

- Stability – The rule measured initial stability, by the righting moment at 1^{O} (RM_1). It also accounted for the stability contribution of the crew sitting on the deck edge. In the balance of hull versus crew stability, designers found that the rule rewarded them when sacrificing hull in favor of crew. This became painfully apparent during the 1979 Fastnet Race, which found that many of the yachts had very low ranges of stability (The importance of the range of stability is explained in more detail in a recent Association Newsletter, Part 3 subtitled, "S&S Swan and 1979 Fastnet Race").



However, an extreme example that took advantage of the sail area part of the Rule is best illustrated by the yacht CASCADE, at 38' (11.6 M), a Milgram design. She is described as a Cat-Ketch rig. While she did garner many successes, she didn't cause a revolution in sail plans. But she served her purpose by fomenting debate on the Rule's ability to fairly measure sail area. This led to the closing of the "loophole" that gave her favorable treatment.

- Sail Area – As a yacht carries a multitude of sails, because of their variations in weight, size, location, attachment extent and methods, etc. there are a myriad of ways for a clever designer/sailmaker to find ways to exploit the Rule. In the case of the Swans, their rigs were very typical for their time. There was nothing unusual about them, so no further comments are made here.

Evolution of Measurement Methods

As noted earlier, contemporary handicap rules have become more complex. There are two fundamental reasons for this. The first is to better predict speed, the second to codify as many variables as possible in an attempt to "plug the holes". A very desirable secondary benefit is that the kinds of hull distortions that were optimizations under IOR no longer receive favorable treatment.

That second reason has a lot to do with the measurement and computational tools which have evolved over time and are available today, as follows:

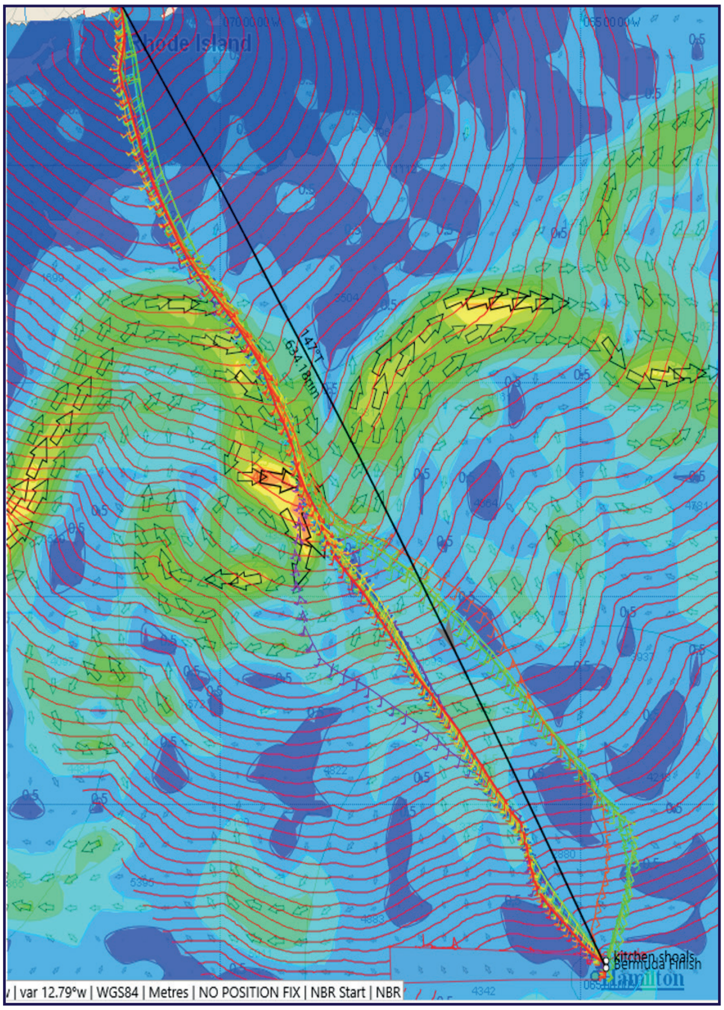
- Lines – As an alternative to using a tape measure to acquire all the data needed to rate a design, the modern rules use survey devices to create a very detailed and thorough "map" of the 3-D geometry of hull, keel and rudder. This map is represented as a family of stations, transverse "cuts" through the boat, from bow to stern, saved in what is termed the "offsets file". The current standard measurement equipment is the laser scanner. Software stitches together a series of scans into a single cloud of measurement points from which the family of stations is derived.
- Displacement – Under earlier ratings rules, the freeboards were measured. The designer would use those measurements to calculate, and provide, the displacement. Today with the detailed shapes of hull, keel and rudder represented in the "offsets file", those same freeboards are used with standard naval architectural software embedded in the rule to calculate the immersed volume, multiply it by the measured water density and it provides an accurate displacement. It is also possible to suspend the yacht with a single point lift and directly measure the weight with a calibrated scale.
- Computer – The development of small computers has made it possible for measurers to pre-check their findings before leaving the yacht. And as noted earlier, because the rule is computationally complicated, the computer is ideally suited to provide fast and accurate results. Computers are also well suited to calculate time allowances and yacht standings at the end of a race. The benefits are twofold. It minimizes mistakes and can quickly provide results. In fact, taking it a step further, with a portable computer aboard the committee boat, the committee can

determine the corrected finishing order in real time. The results could then be shared at the club bar after the race. (Prior to computers we had to wait until the next day to read about the results in the newspaper.).

Conclusion

The authors are of the opinion that over time the rating rules have become better predictors of the potential speed of a yacht. And they will continue to evolve. Perhaps new technologies can be brought to bear on the subject as well as having a better understanding of the physics, hydrodynamics, and aerodynamics. Over the years, for example, with increased computer capabilities, computational fluid dynamics (CFD) has become more accurate and more widely used. And looking toward the future, other tools may develop which we can't even imagine at this time.

There are, however, huge obstacles which make it virtually impossible to absolutely predict speed. These are determined by a higher authority than man, being mother nature. How can we ever know the wind direction, speed, and sea state, one or two days before the start of a race? A recent step which begins to address this very issue was implemented for the 2024 Newport to Bermuda Race. This new scoring system, termed Forecast TCF (F-TCF), uses wind and current forecasts, boat speed polar tables, and optimal routing to calculate the fastest elapsed time possible for each boat. These elapsed times were used to develop time correction factors (TCFs), for time-on-time scoring, that were specific to the expected conditions of that race. This approach rates each boat for the conditions that will exist while that boat is on the racecourse, thereby

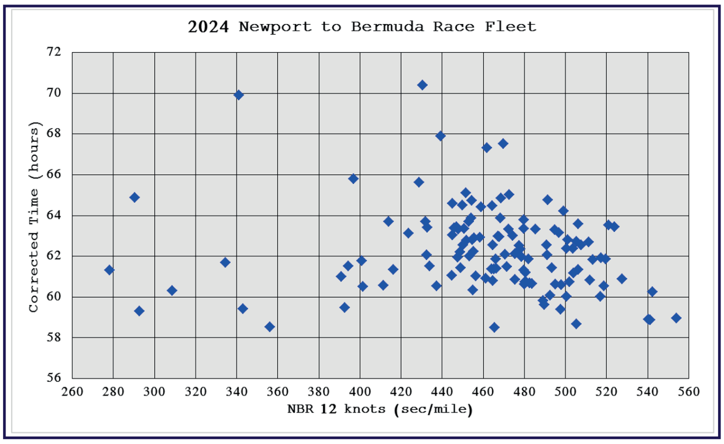


The image on the left shows the theoretical optimal routes for several of the boats in the 2024 Newport to Bermuda Race. These were calculated with the routing software in Expedition using polar speed predictions from the Offshore Racing Rule (ORR) and wind and current GRIB files. This result shows all the boats heading West of the rhumb line to take advantage of a SSE flowing Gulf Stream meander, then diverging into several different paths that would depend on the performance characteristics of the boats and the different winds they encountered. Each boat was rated using its best elapsed time in the conditions they were predicted to experience.

Re-scoring of past races with F-TCF showed the method did greatly mitigate the unfairness that results when some boats, no matter what they did and where they went, were going to face less favorable wind and current.

mitigating the unfairness caused by variable weather that might favor fast or slower boats.

The graph in the next page shows a preliminary scoring of the 2024 Newport to Bermuda Race. The horizontal axis is an ORR predicted speed in 12 knots of wind for typical wind speeds and directions for the race. Its use here



is simply to separate the boats, fast on the left, slow on the right. The vertical axis is the corrected time, equal to the product of each boat's elapsed time and its TCF (again, time on time scoring.) What is very encouraging is that the boats with low corrected times, those that did well, are distributed all across the boat speed spectrum. The scoring did not favor any particular part of the fleet. To some extent this reflects wind conditions that were relatively similar for most of the boats. To a much greater extent, the fair scoring was due to F-TCF taking into account the effects of the Gulf Stream. That favorable current benefitted the slower boats much more than the faster ones. It is also true that the wind at the end of the race was more favorable to slower boats, a feature captured by the wind GRIB file used for the routing and scoring.

Weather based scoring methods, such as F-TCF, will be used more often in the future. The Transpac Race from San Pedro California to Hawaii has committed to its use for 2025. The race has three different start dates, each separated by two days. Using separate coastal and offshore wind forecasts for each of the three starts will help reduce the scoring unfairness if the coastal conditions are not constant for all three days.
Should by some miracle, all the variables come together with the highest level of precision, than we have found the HOLY GRAIL. The downside is, we won't have anything to complain about at the yacht club bar, after the race.

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Jim Teeters, a graduate of Stevens Institute of Technology, joined Alan Gilbert and the design team at Sparkman & Stephens in 1983 to help with their America's Cup effort. A 17-year career at S&S provided Jim the opportunity to find and pursue his passion: exploring the science of sailboat performance and helping create methods that apply that science to the rating/handicapping of race boats. Jim is the technical manager of the ORR system used for offshore racing in the US as well as Head of the Offshore Ratings Office at US Sailing. In the latter capacity he oversees the implementation of the measurement rules ORR, ORC and IRC used for offshore racing.

Alan Gilbert is a graduate naval architect, ocean, and marine engineer. He has devoted his career to the design/ engineering of both power and sailing yachts, in all sizes, and in various materials. His familiarity with S&S Swans results from his 27-year tenure at S&S. He ultimately became Chief Engineer, and Executive Vice President. During this time the majority of S&S Swan models were designed