Putting Numbers on Iceboat Performance

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While there has been no shortage of speculation on top speeds, ice boating has been a hard sport to put valid performance numbers on. My effort to get a proper perspective started in earnest with the purchase of a good quality radar gun in the early 1990s. That did a pretty good job at sorting out the velocity picture but did not say much about angles (see 1993 article: 'Boat Speeds' on the DN website).

In our speed project with the Wood and Iron Ducks on dirt we have evolved from using timing traps to radar and are now using a sophisticated GPS. The GPS method has the significant advantages of allowing the freedom to sail wherever the wind takes us the fastest and avoiding the risk of having to sail fast at a measurement station. There is more information on speed measurement on www.NALSA.org (particularly the Speed Record pages and the 11/99 newsletter).

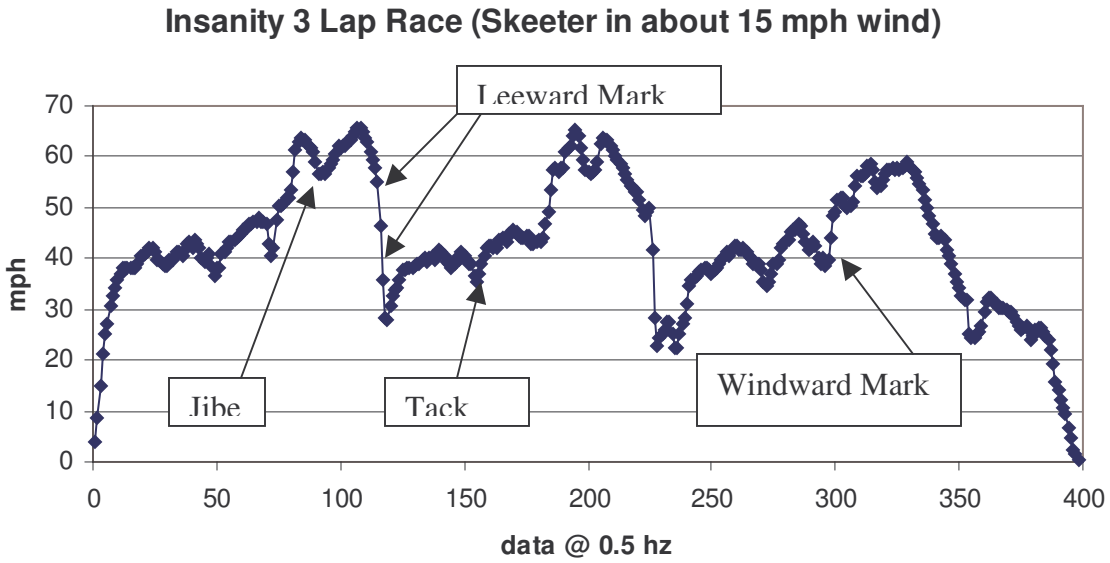
The GPS we are using is a Trimble AG 132 with a Trimble data logger borrowed from a friend who works for the company. This system is by far the most accurate and comprehensive system for velocity we have found. The fixed position measurement uncertainty of the AG 132 (with the filtering turned off) is only 0.03 mph! I also have done careful time over distance tests and found the GPS accuracy is at least as good as my test methods.

For projects other than setting speed records an inexpensive GPS with a data logging system is a good solution. These units are surprisingly accurate. The 0.1 mph accuracy claimed by most units seems to be valid most of the time based on comparisons of logs recorded simultaneously on the AG 132 and several Garmin hand-helds (see 'spurious data' discussion below).

Finding a good logging system was a problem until I found Kjeld Jensen's Cetus GPS logging software for Palm OS PDAs (www.cetusgps.dk/) It is free, easy to use and very well thought out. Cetus collects the following data every one or two seconds (depending on the GPS)

- Position
- Time
- Velocity
- Bearing
- Satellites in view
- HDOP (the quality of the view)

Using a conversion utility from the Cetus site you can convert the Palm database format to a text file that can be loaded into a spreadsheet. The simplest and one of the most informative things to do is to graph the velocity. With a little effort you can identify the various maneuvers associated with velocity changes. It is an eye opener to see how much ground is lost in a tack.

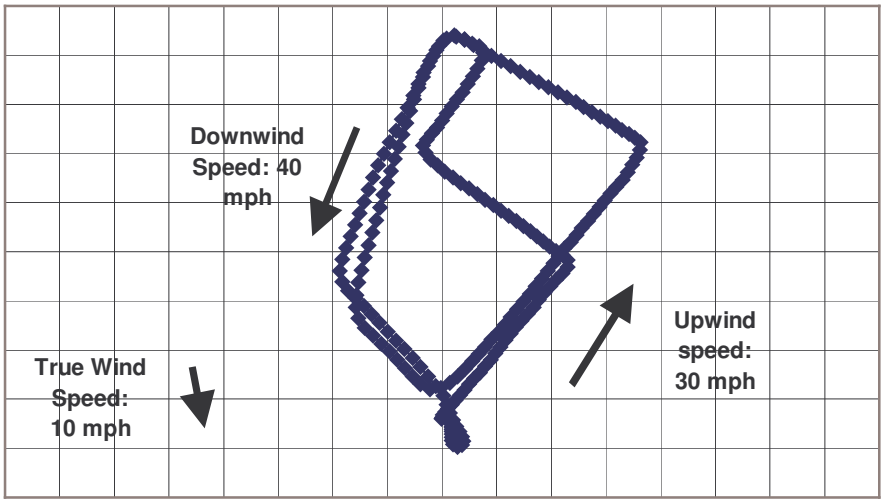


Note for any non-ice boating readers: The Skeeter is the most advanced class of iceboats. It is certainly the most efficient and, arguably, the fastest on ice. The best Skeeters are about 32 feet long, 22 wide with a 27 ft mast. The total sail area (including the mast and boom) is about 120 square feet. The all up weight is about550 lb. The DN is the most widely sailed iceboat in the world. It can sail about 6 times the wind speed in light winds and tops out a little over 60 mph. It is 12' by 8' by 16' with 60 square feet of sail and weighs about 150 lb.

Skeeter with DN behind

You can also do the trigonometry of the positions and do an XY graph of position to show the track of the yacht. This gives a nice perspective on the angles, speeds and distances.

GPS Plot of Two Lap DN Race



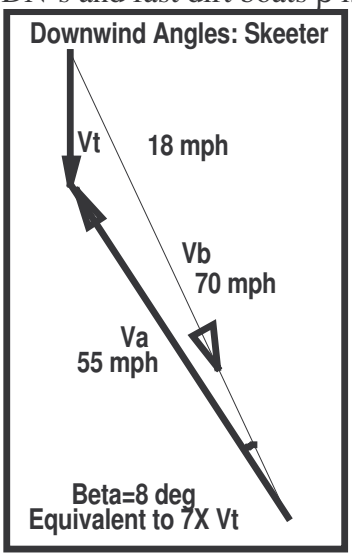
500 foot grid

You can go through the numbers in the spreadsheet and find the tacks, jibes and roundings by changes in bearing. From this you can calculate the cost of the maneuver in time and distance. You can also calculate the true wind angle by averaging the bearing on each leg. With that and a reasonable estimate of the true wind velocity you can calculate the whole velocity triangle. Beta (β) is the angle between the apparent wind and the yacht vector. It is a good estimate of the efficiency of the yacht.

You can compare the results from yourself and your tuning partner or the whole fleet…there is just no end to how much time you can spend winnowing out information from all the data you can generate. However, no GPS data is necessary to know if you are going slower or not pointing as well or, most of all, not getting to the finish line first. What the data does do is put numbers on what is otherwise obvious. I doubt this data analysis will offer any shortcuts to the NA championship.

From the DN data in medium winds strengths, the speed loss in the tacks is about 7 mph (out of 32). This results in distance losses averaging 130 feet involving about 30 seconds between when the boat starts to slow and when it is back up to the pre-tack speed. For a jibe in these conditions the distance loss is about half as much. On a big race course in a big fleet there are lots of other factors to consider as evidenced by the tactics of the best sailors who often demonstrate the benefits of a couple extra tacks.

The apparent wind/yacht angle (β) is where iceboats, and particularly Skeeters, are King. The apparent wind angle (β) is surprisingly low for very efficient boats like Skeeters (6 to 7 degrees). This is equivalent to sailing at 8 to 10 times the wind speed and they are, in fact, capable of this feat in light winds on good ice. In DN's and fast dirt boats β is more like 10 to 12 degrees.



Vt=wind speed, Vb=boat speed, Va=apparent wind seen by yacht

Data Quality and Accuracy

When everything is working right, GPS's are very accurate relative to most other measurement methods. The larger issue is that they can give spurious data when things are not working properly. Usually spurious readings are outside the believable range, but not always. The two most common reasons I have encountered are weak batteries or a poor or rapidly shifting view of the sky. Filtering can also be an issue. Particularly at lower speeds or when there are abrupt changes in direction or speed.

A fresh set of batteries is well worth the minor cost involved. Lithium batteries have long life, do well in the cold and are a bit more expensive. For a reliable sky view, I have had mixed

success with carrying the GPS in a pocket on top of my chest. Side pockets are even worse. The best place is securely taped to the deck in front of the mast.
The 'Max Speed' function is convenient and generally accurate but it is a single point with no supporting data. If you log the data you have a better basis for confidence in the top speed values. As a point of perspective a modern DN is probably capable of 70 mph but speeds that high are very rare.

Filtering helps a GPS make the best guess in a tricky situation. It is also used to keep the unit from being confusing . For example manufactures don't want you to think that your GPS is moving when it is standing still so they filter out low speed readings. This is called 'Show Room Mode'. 'Tunnel Mode' tells the GPS to hold a reading for a few seconds when the signal goes away. 'As you were' mode tells the GPS to keep doing what you were doing. This shows up sometimes when there is an abrupt change in velocity or direction. While filtering causes some velocity errors these units do a remarkable job of telling you where you are and how you got there. When these errors do occur they are generally obvious when you look at logged velocity data.
Unlike inexpensive units the Ag 132 can be configured to turn the filtering off. This allows measuring the fixed position 'speed' which is really the measurement error. This is valid for both a static or moving GPS because the satellites are moving at several thousand mph relative to the GPS. From their standpoint the GPS is moving very quickly at either 0 or 100 mph.

Spotting Errors In Logged Data
Most of the times I have found bogus data it is related to a poor view of the sky. The following are several things to look for:

- If the number of satellites is below about 6 or the HDOP is over 3, the view of the sky may be a problem.
- Calculate the accelerations and if they are more than -15% or +8% of gravity the data may be bogus (more simply if the speed decreases by more than 6 mph or increases by 4 mph in a two second interval you may have bogus data or the boat did something memorable like spun out). The biggest speed changes occur during tacks or rounding the leeward mark.
- Look for unchanging speed values. More than two identical values is suspect.
- Look for unrealistic speeds, time gaps, etc. All of this can be done with simple spreadsheet functions.
- The velocity = f(time) plot is another quick way to spot dubious data.

Hardware
You need a GPS, a Palm Operating System PDA (you do not need much memory as the Cetus track.pdb files are very efficient), GPS data and PDA hotsync cables, a null modem connector and a gender changer (Radio Shack). Duck tape, packaging tape and/or a velcro covered cloth bag are helpful for mounting the GPS in a convenient place with a good view of the sky.

I have missed a lot of data because one of the connections failed or the logging function was not started properly. The Etrex connector has been particularly troublesome. Careful application of duct tape strips and wiggling things to assure the connection will last is well worthwhile. It is also easy to not have the software set up properly. This usually happens when you are rushing to get the instrument on a boat near the start of a race. Careful preparation goes a long way.

I have used several GPSs. I like Garmins but they all have a 2 second time interval for NEMA sentences (data output). Two seconds is fast enough to get a good understanding of most of what happens on an iceboat but more data is always nice. I recently got a Magellan Meridian Gold that will output at one hertz. I tested the track log on the Magellan. It will put in data points every second or so at speeds above 40 mph but the speed data is inaccurate. There is a two second swing in the velocity averaging about 2 mph (ranging up to 7 mph) when the boat was going at nearly constant speed so it is not much help. The Cetus system works much better than the track log.

Software

You need to know your way around your GPS setup, the PDA and the Cetus software. Cetus has an excellent guidebook on their site. It may take a little trial and error but it is pretty straightforward.

As you get data that you feel are representative of different circumstances I would love to see it. In spite of logging data for three seasons I have yet to get good data for racing in winds over 20 mph or reasonably pure light wind sailing.

Happy Data Logging,

Bob

PS: Now that you have read through what we are trying to achieve does anyone in the Cetus community have answers to some of the following questions?

1) What GPS units will transmit data to Cetus at 1 hz?
2) What units will show speed at 0.1 mph resolution above 100 mph?
3) What units have filtering that can be turned off?
4) I would love to get rid of the wires and the connection problems. Any suggestions for a GPS that will attach to a Palm OS PDA into one unit with longer battery life, more ruggedness and less cost than the Palm/Garmin I Que?
5) Any suggestions for a bluetooth system?
    a. Can I expect to mount the GPS on the deck of the boat and put the PDA in the skippers pocket and still get reliable data transmission?
    b. There is a wide range of bluetooth GPS prices, any suggestions on models that are likely to work well for this application?
6) Any other suggestions, corrections or questions?

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