Observers Report for a NALSA Dead Down Wind Record Attempt

And

An Attempt for a Top Speed Record in the Non-Conventional Sailing Craft Category

Written by Bob Dill and approved by Kimball Livingston

Summary: The Thin Air Designs Team spent July 2 and 3, 2010 on the west end of El Mirage dry lake attempting to set a NALSA DDW record with their Dead Down Wind craft Blackbird. It was piloted by Rick Cavallaro. JB Borton managed the support and measurement operation. As discussed in detail below, we support their claim of achieving 2.8 times the wind speed at 27.7 mph craft speed. In a separate run the team also claims to have achieved a maximum speed for a Non-Conventional wind powered craft of 51.4 mph. We are confident this claim is valid as well.

Compliance with the NALSA Record Regulations

C4: As outlined below Blackbird meets the requirements of NALSA record category C4. The craft clearly demonstrated the ability to accelerate while sailing dead down wind. Iceboats are also well known for being able to sail deep downwind in high winds. The deepest I have measured (and deepest measurement I am aware of) is about 25 degrees off DDW (Dan Clapp, 17 mph wind and 70+ mph boat speed, Lake Champlain 2003). In theory a similar iceboat could sustain a speed of 85-90 mph at 15 degrees off DDW in a 30 mph wind (this is well in excess of the wind speed Skeeter Iceboats normally sail in). Blackbird's average angle to DDW through the measurement period in the proposed record run was 5°.

S1: The vehicle was powered by wind energy only. There was no evidence of any other source of power.

S2: We found no evidence of any energy storage devices. There has been some discussion on www discussion groups that the rotating propeller constitutes a form of stored energy that might be converted to propulsion by slowing it down or changing its pitch. Since the propeller is connected to the wheels with a constant ratio connection slowing the propeller to harvest some of its rotational energy also slows the craft. The fact that the craft is required to accelerate during the measurement means, for a fixed gear ratio craft, that rotational energy is being added to the propeller to speed it up during the measurement period rather than the other way around.

Adjusting the pitch of the propeller can make the craft accelerate more strongly just as sheeting in the sail can have the same effect on a conventional sailing craft. This is a normal part of sailing: the sail (or propeller in this case) is adjusted to maximize its ability to add forward velocity to the craft.

Operation of controls: All controls were operated by Cavallaro with no use of stored energy.

S3) The yacht demonstrated, on several occasions, that it would start from a dead stop in winds similar to the wind in the record run. This takes a bit of time and distance, so most of the runs were push-started by JB on foot as allowed in S3.

S4) El Mirage, like most dry lakes, is very flat. Normal flooding patterns on the lake clearly indicate that the section we sailed in easily complies with S4.

S5) Rick Cavallaro, as the pilot, signed a statement saying he agreed to the provisions of S5.

S 6) This is the first time measurements for this record were made and the process was heavily instrumented. Blackbird had three GT 31 GPSs. The chase vehicle had a Met One 34B weather station (wind speed and direction) and a Novatel GPS both feeding into a data acquisition device (DAP) at 5 hz. In addition, there were two GT 31s on the chase vehicle (each with its own logging system). There were two additional 34Bs at fixed downwind positions with Novatel GPSs and DAPs. These were either mounted on vehicles or were portable to allow them to be positioned where the craft was expected to pass within 200 feet during the measurement period. The static measurement uncertainties of the Novatel GPSs were about 20% better than the GT 31's, which have about 6 times better certainty than NALSA requires.

A Measurement Plan was submitted to the observers and is included with this report.

S7) Kimball Livingston and I acted as observers.

Observer Qualifications: Kimball is an author and Editor at Large for Sail Magazine. He has long experience in a wide range of sailing craft and is familiar with land yachts. He has carried out official duties at many sailing events, including laying courses and acting as line marshal at a world championship of the Star Class. I have considerable experience building and sailing high speed land yachts, measuring performance on land and ice yachts, developing the NALSA Regulations for Speed Record Attempts and running ice and land sailing events.

Additional observers, unofficial: A number of people not affiliated with the Thin Air Design (TAD) Team were present during the trials, including Richard Jenkins (current top speed record holder) and Doug Frasher, Bengt Johansson, and Dean Shaw of the Volvo design team in Los Angeles. Emilio Castrano Graff and Dean Baker showed up with their own small, unmanned, radio controlled DDW craft. Four engineers from Joby Energy flew down from Santa Cruse and landed on the lake bed to witness the record attempt. Other members of the Thin Air Designs team included Dave Glover, Steve Morris, and Chris Fields

As outlined below, we saw no evidence of any intent or attempt to circumvent the rules. The quality of the TAD measurement systems was very good. I am competent to operate the measurement instruments and I state with confidence they were used properly.

S 8) This package of reports will consist of a report of the data by the Thin Air Designs team, this observers' report and the measurement plan.

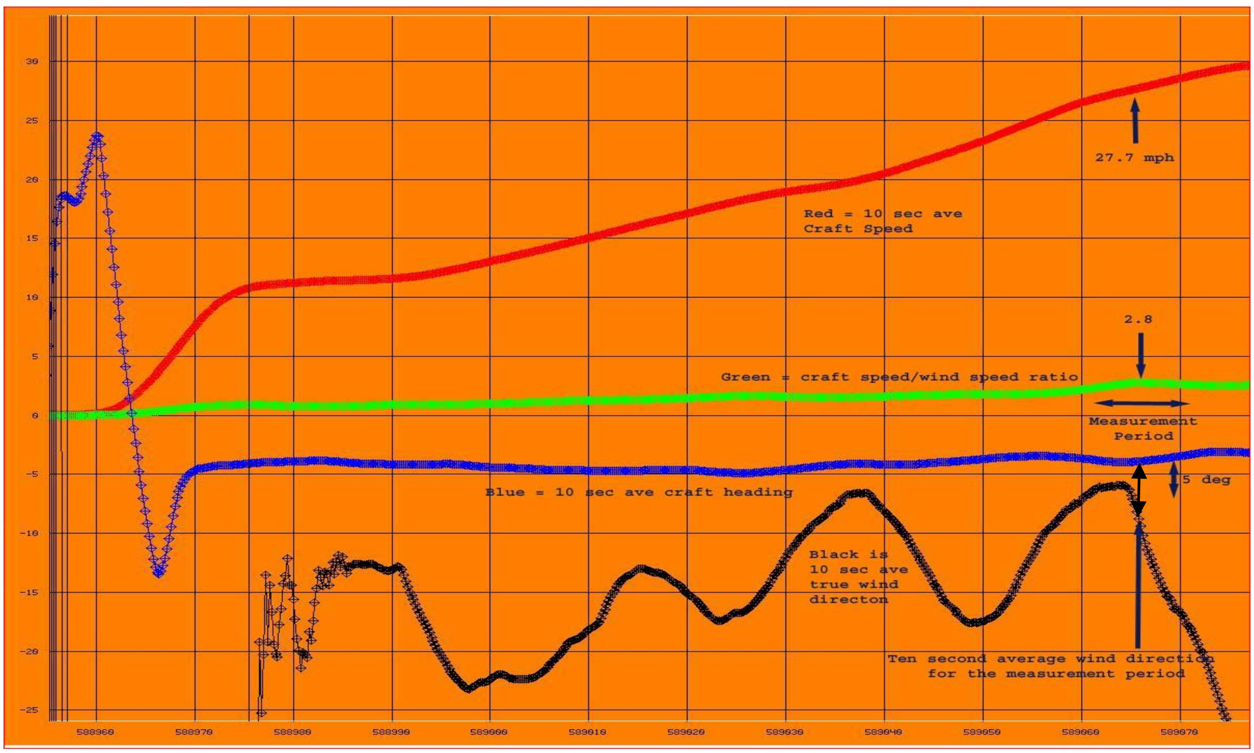
Kimball and I are confident that measurements associated with the run being submitted are scientifically well within the NALSA requirements. From an ethical standpoint the Thin Air Team has been very open in all aspects of their measurement and analysis process. All the raw data was provided promptly (over 60 MB!). There is no hint of any data subterfuge and little likelihood that such subterfuge could go undetected.

Accurate wind measurements are difficult to make, given fluctuations in wind speed and direction over time and position. To resolve any reasonable doubts, the TAD team developed an effective and sophisticated system for measuring the wind field. Wind speed measurements from the craft itself were not used, as the TAD team had previously identified a roughly 1 mph favorable bias in wind speed measured at the front of the craft. The two stationary weather stations were used as secondary instruments.

Anecdotal note: From my position at the top of the course, sighting downwind from behind the craft at the beginning of each run and then jumping aboard the chase vehicle for many of the runs, I had the unique opportunity to observe at least six runs in their entirety. I can state unequivocally that my eyeballs agree with the data—Kimball

S 9) The average craft speed from the measurement period was 27.7 mph (rounded from 27.665).

DDW 10) The craft was 5° off DDW during the measurement period, comfortably within 10° of the true down wind direction during the measurement period . During the in-run it averaged under 10° off DDW after a brief excursion to 17-19° early in the run.

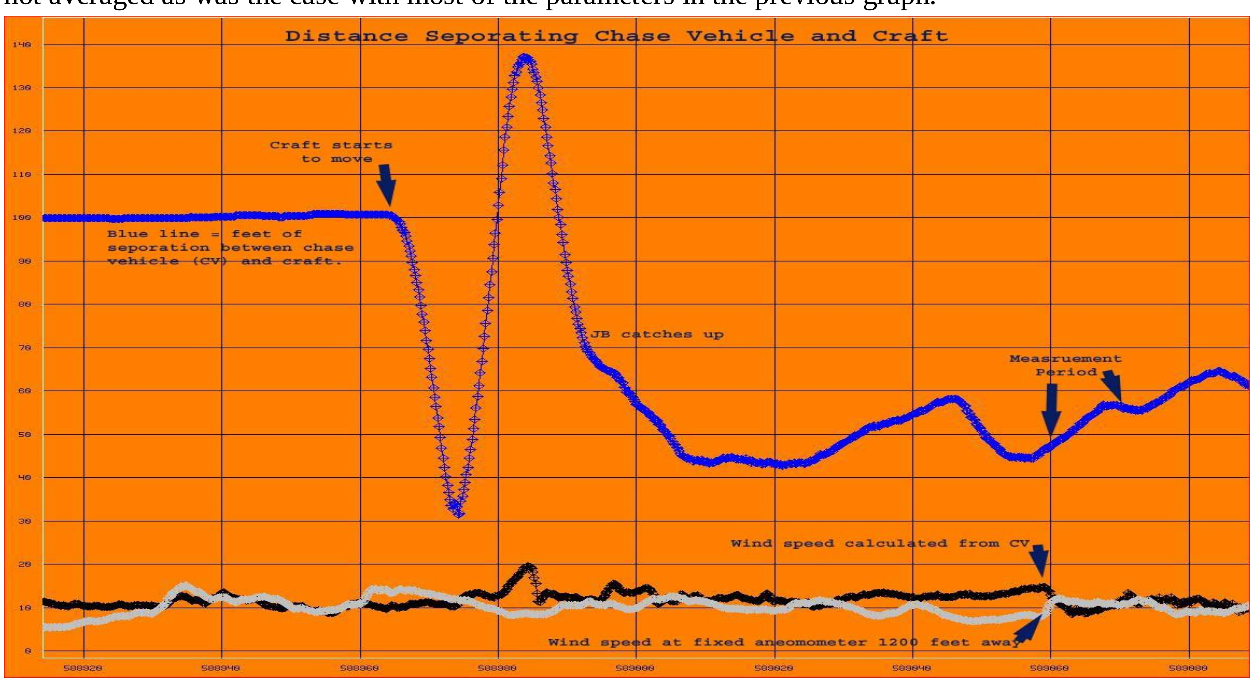


This graph is an image taken from Ricks AnaGraph program. It shows the 10 second averaged craft direction (blue), 10 sec averaged. wind directions (black), 10 sec average craft speed (red) and un-averaged ratio of craft speed to wind speed (green). Bear in mind that, on this graph, a single point at time 589065.8 sec represents the measurement period for the wind direction, craft direction and craft speed. The center of the 10 second measurement period is 589065.8 seconds (the time convention is: seconds past midnight (UTC) from the previous Saturday). It is easy to be confused by the black line getting more than 10 degrees off DDW late in the measurement period. Every point on the black line after 589065.8 includes some measurements from after the measurement period is over. The ratio line (green) is the only line on the graph that is not a 10 second average. Observer Appendix A goes over the measurement period in considerably greater detail.

DDW 11) After reviewing the data the Thin Air Team chose the first run on Saturday. It was run in light wind (10 mph). The craft speed over the 10 second measurement period averaged 27.7 mph. The entry speed was 27.0 mph in the first second and 28.4 mph at the exit. This is seven times more than the 0.2 mph required increase.

DDW 12) The Met One units have calibration certificates traceable to NIST with an uncertainty of about 1% (1/3 of the NALSA requirement). The response rate to a change in wind speed of the MetOne anemometers is they get to 68% of the new wind speed for every 10 feet of wind that passes over the cups. This is about half a second in a 20 mph wind. After a sudden change in wind speed, the cups will be within 1% of the new wind speed in two seconds. The wind direction measurement has an uncertainty of one degree. The direction set-up process has an uncertainty of about one degree as well. The combined measurement uncertainty is about 35% of the NALSA allowable uncertainty of 4°. All primary wind speed and direction measurements were made at propeller hub height. The true wind speed and direction were calculated from the vector sum of the speed, heading and apparent wind of the chase vehicle and the speed and heading of the craft. There is some increase in measurement uncertainty from 'subtracting large numbers' effects. It is the feeling of the observers and TAD team that this uncertainty increase is not excessive and is an appropriate tradeoff for the advantages of taking measurements in closer proximity to the craft while avoiding the confounding effects of the large propeller.

The following image is an annotated graph showing the separation between the yacht and the chase vehicle(blue), the true wind speed calculated from the chase vehicle and the true wind speed at a static measurement station about 1200 feet further downwind during the measurement period. Note: this data is not averaged as was the case with most of the parameters in the previous graph.



DDW 13) The primary off board wind direction and velocity measurement instruments were on the chase vehicle. As seen on the blue line above, the chase vehicle briefly got about 140 feet away as JB ran back to the chase vehicle after push starting it. During the measurement period he was 48-57 feet away. Note: there was also good agreement between the chase vehicle true wind values and a fixed anemometer (1200 feet away). This reflects the relatively steady wind speed when this run was made.

One of the reviewers of this report pointed out that the true wind speed (black line in separation graph) was 4-5 mph faster a few seconds before the measurement period(MP) than the speeds during the period yet it continued to accelerate in the lighter winds present in the MP . This brings up the question if there is some way the energy associated with the higher wind can provide acceleration during the measurement period. The observers see no meaningful way this could happen without using stored energy. Blackbird has no such capability. In effect the higher wind speed before the measurement period got the craft close to its equilibrium speed more quickly but it would have gotten there if the wind had stayed at exactly 10 mph for the entire run. The craft's ability to accelerate is proof that it is more than able to sustain its speed in the wind it is sailing through at the time and, therefore, is an appropriate basis for calculating a 'craft speed to wind speed' ratio. On this run the Blackbird accelerated from well before to well after the measurement period. As noted on Appendix A the equilibrium speed ratio for Black Bird appears to be a little over 3.0 to1 in a 10 mph wind (based on shorter measurement times and the amount of acceleration occurring at different wind speeds).

When the NALSA regulations for DDW sailing were developed the measurement period was increased from 3 to 10 seconds to make it unlikely the speed ratio could be significantly affected by allowable flexural energy in the craft (See S3 comments in the regulations) and the higher measurement uncertainties associated with making the wind measurements. We believe the longer period is effective for getting a proper measurement of the speed ratio.

DDW 14) The DAP data (GPS, wind speed and direction) was collected at 5 hz and the GT 31 GPS data at 1 hz. All of it was time stamped properly.

DDW 15) This does not apply as this is the first record set in the C4 Category.

Observers' Conclusion on the C4 (DDW) record attempt: We recommend that the NALSA Board ratify the first record in Category C4 of 2.8 times the wind speed for the craft Blackbird, piloted by Rick Cavallaro and designed and built by the Thin Air Designs team. The record was set in a 10.0 mph wind.

Observers Report for a Top Speed in a Non-Conventional Wind Powered Craft Record Attempt

Summary: The observers are confident that the Blackbird set a record for top speed in the Non-Conventional wind powered craft category (C3). The craft achieved a top speed of 51.4 mph at 14:19:16 PDT on July 2, 2010 on El Mirage dry lake. The estimated wind field at the time ranged from 14 to 28 mph with an average of 21.

Compliance with NALSA record regulations

C3) Blackbird meets the requirements of Category C3 because it is propelled by a propeller.

Compliance with Rules S1-S8: The observers and other personnel were the same and rules compliance information is the same as described above.

S9) This is the first record in this category so an increase increment does not apply.

Additional Information and Commentary

51.4 mph is a three-second average from GPS-Dill-#7 rounded from a calculated value of 51.37. It was attached to the front deck of the craft. The GPS's view of sky was good (9 satellites in view, hdop = 0.9). The secondary measurements were made on the chase vehicle which had three logging GPSs and a Met One anemometer. The Dill #5 and 6 GPSs were on the chase vehicle and they agreed very well with each other (standard deviation of the difference: 0.05 knots) and appropriately well with the craft. There is no spurious data in the logged data for any of these GPSs within 30 seconds of the 3 second measurement period. For that matter, all the GPS logs showed good quality data from a couple minutes after start up until they were taken off the vehicles 4 hours later.

Observers' Conclusion on this C3 speed record attempt: We recommend that NALSA ratify a first top speed record of 51.4 mph in Category C3 (Non-conventional sailing craft) for Blackbird piloted by Rick Cavallaro of the Thin Air Designs team.

If any NALSA Board Member has questions or would like to see additional data or information on any of the above please contact either of us.

Bob Dill and Kimball Livingston 7/20/2010