Observers Report for Proposed Records for Dead Upwind Sailing and Maximum Speed for a Turbine Driven Craft

Written by NALSA observers Bob Dill and Kimball Livingston,

Summary

A successful attempt for a dead-upwind-faster-than-the-wind (DUW) record was made by Rick Cavallaro on New Jerusalem Airport near Tracy California on June 16, 2012, with the wind turbine driven sailing craft, *Blackbird*. Mr Cavallaro achieved a maximum boat speed to wind speed ratio of 2.1:1 and a maximum speed in a wind turbine driven sailing craft of 22.9 mph on a different run. The observers have reviewed the data from the June 16 trial, and we are confident the relevant data is valid. We are equally confident that *Blackbird*, the measurement process and the pilot (Rick Cavallaro) complied with Revision 4 of the NALSA Regulations for Speed Record Attempts that were approved by the Board in early June 2012. We recommend that these records be ratified by the NALSA Board of Directors.

The records being submitted for ratification are:

1. Category C4: Sailing directly upwind at 2.1 times the true wind speed (9.9 mph) in turbine mode.
2. Category C3: Achieving a maximum speed of 22.9 mph in turbine mode.

The following is a review of the compliance of the data from the measurements period for the proposed records with the NALSA Regulations for Speed Record Attempts.
Note: the terms 'craft', 'cart' and 'yacht' are used interchangeably in this report, the Submission Report and the NALSA regulations.

S1 (Wind powered only): The observers looked for any sources of propulsion for *Blackbird* other than wind. None were found.
S2: No stored energy was found on the craft other than batteries allowed for instrumentation. Stored energy in the form of momentum of the wheels, the turbine, or in the form of elastic strain energy were found to be consistent with normal sailing craft. These were deemed to be a normal part of sailing, not contributing in a meaningful way to the propulsion of the craft. All controls were operated directly by the pilot.
S3 (Starting): *Blackbird* started all runs from a dead stop with no assistance. In turbine mode it strongly accelerates from a stop.
S4 (Course Flatness): The New Jerusalem runway was checked by Dill with a surveying level. It was found to drop two feet over its length. The course met the flatness requirement that it have a down-slope of less than one meter.
S5 (Liability): The pilot (Rick Cavallaro) provided a signature indicating that he understood and agreed with the liability requirement.
S6: The primary speed measurements were made with logging GPS receivers (Locosys GT31s and GT11s owned and operated by Dill). Their measurement uncertainty was determined by the fixed position method and found to be less than half of the NALSA requirement of 0.25 mph. The measurement plan was the same one used for the DDW trial in 2010.
For the C3 speed record in turbine mode (#2 above), the maximum speed achieved by *Blackbird* in Turbine mode was 22.9 mph on June 16, 2012. This is an average over a three second measurement period starting at 17:59:55 PDT. There was no spurious data within 30 seconds of the measurement period or, for that matter, for the entire day on the primary GPS receivers on *Blackbird* and the chase vehicle.
S7: The official observers were Kimball Livingston and Bob Dill. 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 high speed sailing craft on land and water. 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. Bob has 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. Bob, with Bob Schumacher, held the NALSA top speed record for 10 years from 1999 until 2009. Kimball and Bob observed the DUW trials on July 2 and 3, 2010 on El Mirage Dry Lake.
In addition there were several unofficial observers. In particular Tom Speer, a landsailor and aerodynamicist who is currently working for the Oracle Americas Cup campaign and Richard Jenkins, the builder and pilot of several high speed landyachts, one of which (*Greenbird*) currently holds the NALSA C1 and C2 records.

The suitability and effectiveness of the measurement instruments was confirmed by Dill based on tests run on the GPS receivers and the specifications for the MetOne anemometers. The combination of instruments used provided a complete set of primary data. The data from secondary measurements supported the primary data.

Dill verified the calculations used to convert the raw data into final data. Data was transferred to the observers promptly after the trials ended. There was no evidence of subterfuge in any part of the trial, the data generated by the trial or in any of the interactions with the *Blackbird* team before or after the trial.
S8 (Ratification): This report is being submitted to support the ratification process.
S9 (Record increase increment): Both the proposed C3 speed record is a first time record and, if ratified, should be reported as stated above.

Compliance with the NALSA DUW regulations #10 through #15. These only apply to the proposed DUW record (C4)

Category C4: requires that a craft must demonstrate that it can sail faster than the true wind speed. *Blackbird* went significantly faster than the wind on every run, with many ten second periods above 1.7x, while accelerating. On a cruder basis it was obvious that the craft easily exceeded wind speed based on the chase vehicle speedometer and measurements of the wind speed just before and just after runs with hand held wind speed measuring instruments. There is no question that the craft can easily exceed wind speed while sailing straight upwind.
DDW/DUW 10) The wind on many runs was very closely aligned with the runway. Based on calculations by Dill, during the measurement period of the proposed record run, the true wind direction averaged 4.5° off the cart direction which was within a degree of the runway axis. This easily met the +/- 10° requirement. Several other runs with slightly lower craft speed to wind speed ratios also met this requirement. Rick's report looks at the direction data in two ways, both of which come to the same conclusion: the direction requirement was easily met.
DDW/DUW 11) The ten second measurement period chosen started at 5:30:12 PM PDT on June 16, 2012. (88,212 seconds after UTC midnight, the previous Saturday in Rick's time system). The craft speed/wind speed ratio for this ten second period was 2.1:1. The craft speed in the last second was 0.21 mph faster than in the first section. This exceeds the 'at least 0.2 mph' speed increase requirement. Note: In the developing of the NALSA regulations, the 0.2 mph increase was chosen to be the minimum increase that, with reasonable confidence, would demonstrate that the craft was accelerating during the measurement period. Other measurement periods on this and other runs with slightly lower Vc/Vw ratios, had higher speed increases indicating the chosen measurement period was not an outlier, but rather, it is the period with the highest speed ratio that met the requirements of the NALSA regulations.
DDW/DUW 12) The primary wind speed and wind direction measurement instrument (a MetOne 34B) was on the chase vehicle. I spoke with the 34B product manager about what they mean by 'accuracy' in their published specifications. To MetOne, accuracy is a worst case error which is more than the combined measurement uncertainty with a coverage factor of two: ie more than 95% confidence (see a definition of measurement uncertainty in the comments section of the NALSA regulations). The wind direction measurement uncertainty inherent to the 34B is about a degree and the alignment uncertainty was about 2˚ for a combined uncertainty for direction of about 2.2˚, well below the 4˚requirement. For wind speed, the measurement uncertainty is less than 0.13 mph (well below the 0.6 mph requirement).

The 34B was logged at 2 hz (requirement: 1/2 hz or faster). The measurements were taken a few inches over hub height on the chase vehicle and the two fixed position measurement station. The wind speed data is reviewed in more detail in Rick Cavallaro's Report (attached). All the requirements of DDW/DUW 12 were met.
DDW/DUW 13) During runs, the chase vehicle anemometer was always less than 100 feet from the cart and was within 50 feet during the chosen measurement period. This easily meets the requirements of DDW/DUW 13.
DDW/DUW 14) All the GPS and wind data was time stamped as required.
DDW/DUW 15) This is the first DUW record so the 6% increase increment does not apply

Note: We are not aware of another wind turbine based sailing craft having achieved a craft speed to wind speed ratio above 1:1. The highest we know of is 0.75:1 ratio achieved in 2011 by the DTU team's Racing Aeolus craft. On that basis, we believe *Blackbird's* 2.1:1 ratio is a legitimate world record (NALSA C3-turbine mode).

The fastest, turbine-driven, top speed we know of (other than *Blackbird*) is15.3 mph, also achieved by the DTU team's Racing Aeolus car on the same run as their 0.75:1 speed ratio. Based on this, we believe that 22.9 mph is a legitimate world record for maximum speed for wind turbine powered sailing craft. (NALSA C3-turbine mode). For perspective, *Blackbird* achieved an unofficial top speed of about 28 mph in wind in the mid teens on *Blackbird's* shakedown trial at New Jerusalem with a turbine on May 20, 2012.

Conclusion: Based on the above, we recommend that the NALSA Board of Directors ratify the two records outlined above. If any board members or NALSA officers have any questions about this report or the underlying data, please contact either of us.

Bob Dill and Kimball Livingston 7/11/2012