Thunderbird 2012 at SailBot 2012

The 6th Annual International Robotic Sailing Championship

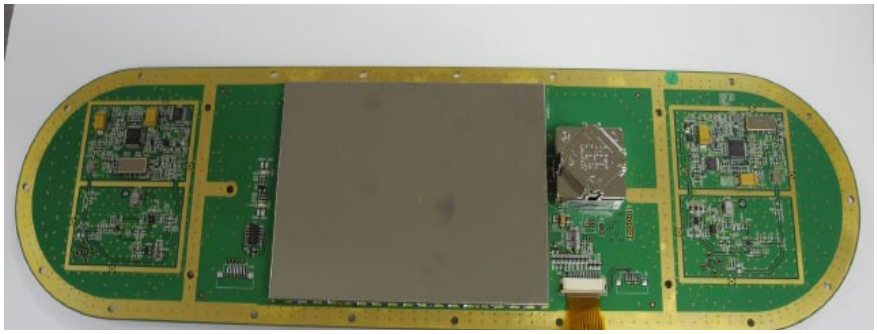
The results of the 6th International Robotic sailing Championship went into the record books on June 14th 2012. The event was co-hosted in Vancouver B.C. by the University of British Columbia and the Royal Vancouver Yacht Club. The UBC team sailing "Thunderbird 2012" took first place followed by Olin College in 2nd. Three time winner; "Gill the Boat" from the U.S. Naval Academy in Annapolis, was 3rd. A record ten boats representing universities from across North America and as far afield as Great Britain took part in the four day long competition.

The most successful SailBot ever: "Gill the Boat" the U S Naval Academy's three time winner. Foil envy - note the beautiful CNC machined titanium keel foil!

The SailBot championship is primarily aimed at undergraduate student teams, the goal is to give engineering students a practical application of the topics they have learned, while also providing an exciting way to learn project management in a multi-disciplinary environment. A successful SailBot combines the disciplines of naval architecture, mechanical engineering, systems and electrical engineering, as well as project management.

This document has been prepared by the UBC SailBot team as a de-brief review and also for our sponsors, friends and supporters as a detailed description of the event and the Thunderbird 2012 project. In 2012 our generous sponsors included: Hemisphere GPS, UBC, RVYC, Babcock Canada, Lloyds Registry, Robert Allan Ltd, STX Canada, SNAME PNW, Teleflex Canada, V M Dafoe, and Western Mariner. We are very grateful for the support from these organizations that made possible the success of Thunderbird 2012.

"Thunderbird 2012" – UBC's successful SailBot – In SailBot 2011 "Thunderbird 1" UBC's SailBot came within a fraction of a point of unseating three time sailboat winner "Gill the Boat" representing the US Naval Academy. "Thunderbird 2012" was a huge advance on last year's boat. While the hull and sail plans look very similar to TB1 there were major changes (30% more sail area in the light wind rig, 25% less weight in the hull and deck structure, 11% less beam). The major changes were in programming, electronics and specifically sensors. After struggling with inferior sensor data in 2011 the UBC team set out to secure the best data sensors available. For their navigation data the team's research lead them to discover Hemisphere GPS. Hemisphere GPS is a Canadian based company that produces high precision GPS devices used mainly in agriculture, marine and surveying.



The Hemisphere GPS Crescent Vector H102 dual antenna GPS board as used

The Vector GPS system by Hemisphere GPS is an amazing unit. As team advisor Don Martin says, "We never

know exactly where we are but we always know it's somewhere in this 20 inch diameter circle". The dual antenna system on the Vector GPS board also allows for hyper accurate compass heading information even when the boat is stopped. UBC credits a large part of their success in 2012 to their selection of the Hemisphere GPS system.

After an extensive investigation into commercially available wind direction sensors the team reluctantly decided to build their own. Ultimately this move was extremely successful. Mounted on a short carbon spar above the aft deck, the UBC wind sensor is based on a Bourns optical encoder which feeds information to a dedicated microprocessor (328 Arduino Nano). This sensor provides 40 readings every 2 seconds and a simple rolling average is used to provide steady wind direction data which is sent on to the auto pilot processor. The result is an apparent wind sensor which allows the boat to steer to apparent wind angle on any course much more accurately than a human helmsperson.
The huge light wind rig used by Thunderbird 2012 has raised the performance envelope significantly. The all carbon fiber spar stands 12 ½ feet tall, probably the tallest spar ever on a SailBot and all this on a boat which weighs 30% less than many of her rivals.

UBC's custom built carbon fiber wind sensor unit built around a Bourns optical encoder. Total weight with spar: 48 grams.

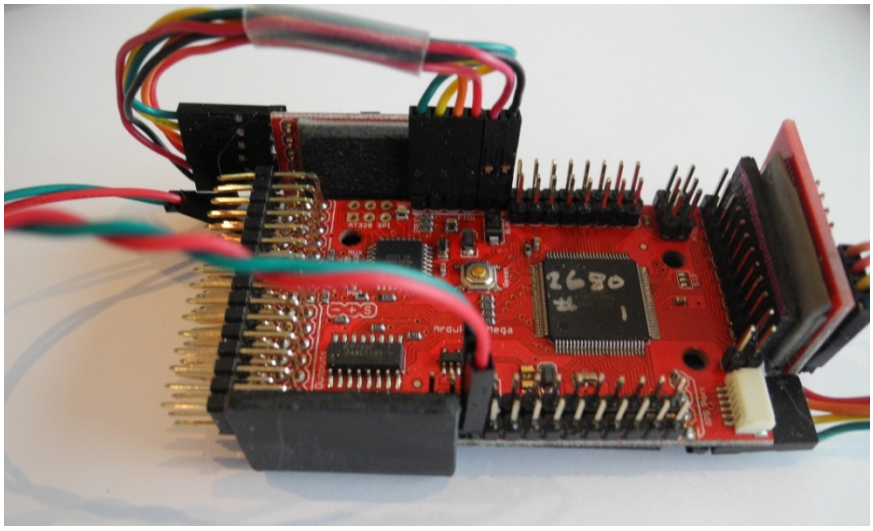
The happy team, part of UBC's 18 member 2012 SailBot team: L to R: Advisors: Dave Cramb & Don Martin, UBC Engineering students: Adrian Granchelli, Karry Ocean, Kristoffer Vik Hansen, David Lee, Advisor: John Kine.

<u>The individual competitions:</u>

Fleet Race #1 – R/C control is allowed in both fleet races. Wind: westerly 8 to 10 knots, small chop, code 0 rig - 12 ½ feet tall. This huge rig provides tons of power for its wind range of 0 to 8 knots. In the R/C fleet races speed is the goal with all boats competing at once. The ability to close our mainsail leech by tightening the vang (pre-start) allows us to point very high in light to moderate winds while keeping the entire mainsail full and drawing. In this race our start went as planned; we started just to leeward of the US Navy's "Gill the Boat" and used our greater speed and pointing ability to force them to tack off and out

into unfavorable current, this allowed us to work into a comfortable lead during the first leg of the five leg course after which we sailed very conservatively for the next four legs to finish in 10 minutes 50 seconds with a 1 minute victory over GTB.

Station Keeping Challenge: The Station Keeping event was held in a 6 to 8 knot westerly with some chop. We used our #1 rig (11 feet tall) which is good in 6 to 12 knots. In the Station Keeping Challenge boats compete individually. The goal is to sail within a 40 M (130 ft.) square box for 5 minutes and then to exit the box as quickly as possible after the 5 minutes are up. Our contest logic worked perfectly. For 5 minutes, Thunderbird 2012 reached slowly back and forth across the 40M square box turning away from the wind and gybing back towards the center of the box each time it came within 15M of the edge of the box. Height in the box was measured by a waypoint located well above the box. When our boat slipped higher or lower in the box, corrections in sail trim and course angle were gradually applied to bring us back to the horizontal centerline of the box. In this contest a bonus point is awarded to the boat that exits the box as soon as possible after the five minute station keeping time is over. Our exit strategy is quite involved. Throughout our run we constantly compare the time remaining to the time it will take to exit using a combination of our fastest and slowest reaching speeds. When the time to exit equals the time remaining our exit procedure commences. During our exit we constantly measure the distance to the edge of the box and determine what exact combination of fast and slow speeds are required to give us the desired exit time. We sail slowly if required and when the time arrives we trim our sails and reach at top speed to complete our exit. A two second cushion is built in to make up for rogue waves (or errors by the timing judges ;<). This year Thunderbird 2012 exited exactly two seconds after the 5 minute period - leading wags to ask us why we included the 2 second cushion – cheeky. Our 2 second exit time gave us the top score for this event (10 points) although Olin College was breathing down our necks with an exit time of 8 seconds. During the Station Keeping challenge significant wave action made maneuvering in the box difficult. Apart from UBC and Olin College, the U.S. Navy's "Gill the Boat" was the only other team that was able to complete the 5 minute stay in the box but their exit time of 95 seconds was well off the pace. Not too many changes planned to Thunderbird 2012's station keeping routine for next year – just a little tweaking on our "height in box" correction routine and a little more work on our exit routine.



The heart of the Auto Pilot system Arduino based AT mega 2680 microprocessor.

Fleet Race #2: Wind: easterly 10 knots – substantial current going downwind. A corroded RC antenna lead kept Thunderbird 2012 out of this second R/C fleet race – shame on our team for falling foul of this sort of defect. Our 2012 program was built around avoiding this type of issue but saltwater has no friends. 41 practise days and we never had this sort of problem before. Too much practise? No – our rear RC antenna compartment was not totally waterproof and a faulty keel bolt gasket allowed water to get into the hull and when the boat was up-ended to drain the water the antenna compartment took on some water. This faux pas almost certainly cost UBC victory in the second Fleet Race which would have given them a perfect 50 point score for the entire competition. This will not happen in 2013.

Navigation Challenge: Wind NNE 6 knots. #1 rig. Substantial cross course current at approx. 0.8 M per sec. The challenge here is to beat upwind for 60 M then run back downwind to pass through the very narrow (3 M / 10 feet) finish gate. In this event the substantial cross course current defeated many teams with only three teams scoring top points (10) for finishing through the central finish gate. On Thunderbird 2012 our strategy was simple and minimalistic in the extreme: we used predetermined compass courses to navigate around the upwind mark then headed back to a waypoint on the finish line using GPS compass heading based navigation. This strategy was a carryover from our 2011 approach which was necessitated in 2011 by our then weak GPS sensor and our poor wind sensing system. This year we managed to navigate through the small finish gate for top points mainly thanks to our powerful Hemisphere GPS system more than anything else. We had not allowed for the possibility of strong cross course current and we were very lucky to be able to complete this event with a top score. Next year we will follow the Olin College team example of having a mid-course, up current waypoint to help guide us into the finish. We will also convert our general course sailing in the nav. contest to use our very reliable apparent wind sensor for steering around the track. With each day of testing we became more and more reliant on our custom built wind sensor. We now know that our apparent wind steering system is far more accurate than any human helmsperson can hope to be under almost all conditions. Our system is based on a Bourns optical encoder although for next year we plan to investigate the use a magnetic encoder.

The smallest of the 3 rigs on Thunderbird 2012 – 8 ½ feet tall. The keel depth is 1.25M (50")

Presentation Challenge: In the Presentation Challenge each team presented their overall SailBot project (mostly by PowerPoint) to a seven person panel made up of University Instructors and Industry Professionals. UBC received top points for this event with Olin College 2nd and USNA 3rd. In the Open Division, the novice team from Cal Poly made a very competent presentation of their complex robotic software approach. A significant part of the presentation challenge judging was based on aesthetics, workmanship and innovation; these areas were definitely UBC's strong suit. In their project description the UBC team specifically addressed each one of the five challenge topics. Using PowerPoint with embedded GoPro video and split screen from onboard and off the boat the team's various program routines were clearly portrayed. The main secret of SailBot (lots of practise) was obvious from the team's many on water testing examples. While the UBC took top points thanks to their strong showing in each of the five presentation topics it was the novice team Olin College who clearly captured the top spot for their control logic. Using a very strong robotics background the team used fuzzy logic to have their boat "teach" itself to sail. Very impressive.

Long Distance Race: 5 Km windward leeward course – twice around – total course length 10 Km. Wind east 8 to 16. Current - E to W 0.4 M/sec. Chop - light to moderate. Rig #1 (11 feet) designed for 6 to 12 knots. The Long Distance Race is always the highlight of the International Robotic Sailing Championship and this year was no exception. The race began with lots of wind and a leeward start which almost proved the undoing for Thunderbird 2012. Our plan was to hang back and make a conservative start. All was going well as we approached the startline; we were 15 M behind the line with the Navy's Sprit of Annapolis between us and the starting line. Seconds before the starting signal was made we switched to auto sailing (and we suppose SOA did as well). Thunderbird 2012 immediately headed directly for the first mark, 0.6 Km downwind. Spirit of Annapolis reversed her course directly in front of us blocking our approach to the starting line. We switched to RC as quickly as possible to avoid them but alas we failed and our ½" balsawood bow bumper came into play as we glanced off the windward stern quarter of SOA as they passed us going upwind, 135 degrees off course, while we ran toward the first mark. In case they felt we had fouled them, we immediately performed two 360 degree turns while still under RC control (30 seconds of RC control is allowed during any avoiding maneuvers and the double 360 is the accepted penalty under the racing rules of sailing for a foul). Fortunately there was practically no damage to our lightweight balsa bow bumper and upon inspection after the race there was no apparent damage to SOA. After this starting line excitement the rest of the race was almost anticlimactic apart from one brief incident when we had to use R/C control to avoid a collision with the Memorial boat while we were sailing upwind on the right of way Starboard tack with them running towards us on Port gybe.

Thunderbird 2012 powering upwind under autonomous apparent wind angle control in the Long Distance contest. Sails twisted, outhauls hard, sheets eased, backstay tight. Wind speed was gusting to over 15 knots - well outside the design range for her #1 rig.

The first long upwind leg was a challenge. We were well above the wind speed range for our #1 rig. (When we choose our rig before the start the wind was strong but we expected it to drop). We had set up the rig for strong winds (open leeches, loose vang, more mast bend than usual, jib leech twisted open. From practise we knew this set up would allow us to sail well even above the range for the rig but changing tacks could be an issue. Our strong tacking routine paid off in spades. In the 12 tacks we made on the first long windy upwind leg (2.5 Km) we never missed a tack. Our tacking routine does far more than ask the boat to turn through 90 degrees. We start by asking the boat to bear off 5 degrees to pick up maximum speed. Next, we head up slowly to ease into the turn followed by maximum helm angle as we pass through the eye of the wind. (there is no point in putting on high helm angle while the boat is well heeled since that merely lifts the back end of the boat and buries the bow slowing down the intended turn and creating huge resistance). Finally, we bear off on the new tack and ease sheets 5% to pick up speed before resuming our upwind course - all this happens in about 8 seconds. The actual time for each tack is based on a lookup table which sets the tack routine for each of four different wind speed ranges. The long distance race has 7 mark roundings, we passed on the correct side and within 3 M (10 feet) of all seven marks. (Thank you Hemisphere GPS). All in all the Long Distance Race was our best event of the Championship.

7 legs into the 8 leg course we lapped the second place boat (Olin College) who was now on their 3rd leg. Our top speed during the race was just over 8 knots (5.6 times root L for those of you that are counting). We also set a new course record, finishing the 10 Km course in 1Hr 59 min.

No other team completed the full eight legs of the Long Distance Course although the phenomenal boat from Olin College completed all eight legs of the course in just over double our time but had two legs disallowed for missing the marker buoys at course turning points. This was due to an inadvertent mistake in setting their GPS coordinates. Olin will certainly be the team to watch in 2013. We have a few changes planned for our LD code in 2013: better layline calculations throughout the course and a more sophisticated tacking routine over varying wind and sea states. Finally, a few super-secret boat and rig changes should give us significantly improved sailing performance for 2013.

Second place went to "Blackbody Radiation" entered by the very impressive novice team from Olin College.

SailBot 2012 Overall Results

	SailBot Division							FINAL
	Team / Boat	Fleet Racing	Station Keeping	Navigation Contest	Presentation Challenge	Long Distance Race	Total Pts	Place
1	University of B.C.	7	10.0	10	10	10	47.0	1
2	Olin College	9	9.0	10	9	6	43.0	2
3	U S Naval Academy GTB	10	9.0	10	8	2	39.0	3
4	U S Naval Academy SOA	8	8.6	7	7	0	30.6	4
5	Memorial University	6	4.4	0	8	5	23.4	5
6	Western Washington U	6	4.5	0	0	0	10.5	6
	Open Division							**FINAL**
	Team / Boat	Fleet Racing	Station Keeping	Navigation Contest	Presentation Challenge	Long Distance Race	Total Pts	Place
1	Cal Poly Pomona	9	10	0	7	1	27	1
2	Iowa State University	8	9	0	6	0	23	2
3	Aberystwyth University	7	0	0	5	0	12	3
4	Tippecanoe Boats	10	0	0	0	0	10	4

What does it take to be successful in SailBot? Based on two years of experience by the UBC team here is what we have concluded are the most important aspects for a successful SailBot project (In order):

1. Early preparation which allows a large amount of on-water testing and de-bugging. (the best kept secret of SailBot)

2. A strong robust platform which includes sailboat, electronics, sensors and programing.
3. Very accurate sensors with very little time lag. It is virtually impossible to program your way around poor sensor information.
4. A good sailboat. The boat needs to be: well balanced, stable, maneuverable and fast. (Remarkably, this is probably the most often overlooked aspect of SailBotting).
5. Electronic systems that will not breakdown in the harsh marine environment (perhaps this should be #1 since during the 2012 event so many top boats failed at one time or another in this area).
6. Simple and sound programing which allows the boat to sail and navigate properly in all conditions. Complete and well developed polar performance data is very helpful here.
7. A comprehensive Graphic User Interface that allows easy access to all performance data via telemetry during testing and competition. The interface must also allow easy data transfer to the boat for testing purposes and for setting competition parameters prior to starting.

"Thunderbird 2012" sailing downwind under the biggest of her three rigs (code 0 rig - 12 1/2 feet - 0 to 8 knots true wind speed)

Thunderbird 2013 – UBC's preliminary plans for Thunderbird 2013 include:

- A new hull very similar to this year's boat but with significantly less total weight (all up weight approx. 1200 Grams less) – the goal is the same stability with less drag.
- New keel and rudder foils designed to be lighter with less drag.
- Totally leak proof hull and deck structure with completely waterproof electronic enclosures.
- Small changes to basic programing. Apparent wind trimming and steering will be used in all four contests. Improvements to Long Distance race navigation logic will be made.
- The very successful Hemisphere GPS system will be retained. Our custom built wind sensor which now uses a Bourns optical encoder may be changed to employ a magnetic encoder.
- Significant development to our Graphic User Interface to allow easier testing and inputting of navigation parameters.

Our Sponsors: And finally one more thank you to our sponsors who contributed so much to the success of Thunderbird 2012:

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