Field Test 1 Report

8/30/2016

Contents

1 Glossary

ASV	Autonomous Surface Vehicle
M-Platform	Main platform of the Robodolf, composed of a forward and rear section.
Pontoon	One of the two hulls that make up the Robodolf catamaran
Port	Left side of a boat
Starboard	Right side of a boat
Hydrostatics	Characteristics of a ship in a static condition, such as trim and draft
Hydrodynamics	Dynamic characteristics of a ship such as maneuvering performance
PTZ Camera	A camera capable of remote panning, tilting and zooming
MFB	Main Frame Box, which is the pelican case that the main computer systems are housed.
BTB	Battery box which is the pelican case that houses the batteries.

2 Test Overview

On Tuesday the 7th of June 2016 the first field test of the RoboDolf ASV was conducted. This field test served as an initial shakedown of all systems as well as an initial sea-worthiness test.

Location: Farrington Lake, East Brunswick, NJ

Personnel: Paul Sammut, John Sammut, Marcelo Magnasco, Kieth, Dimitrous.

2.1 Objectives

A. Test and time field assembly process
B. Check sea-worthiness
C. Test individual systems
D. Test local remote operation
E. Test wireless monitoring of HSR and LSR
F. Test AIP deployment system
G. Evaluate compass calibration procedure
H. Test heading controller
I. Test mission controller
J. Evaluate thermal performance
K. Evaluate battery power performance
L. Optimize disassembly technique

3 Test Details

3.1 Logistics

At the start of the experiment, the vehicle was disassembled to a level where both the battery and the computer box where separated from the vehicle. The M-Platform was taken apart at the middle so that the forward and aft sections were intact. Tower was disassembled down to the tower assembly and 4 legs, 2 of which contained a radio box each.

Figure 1: Top to bottom: Forward M-Platform section, Aft M-Platform section, and battery box.

Figure 2: The hulls of the sea-cycle required 3 people to carry out of the building through the staircase. At 16' long they did not fit a commercial freight elevator.

A 16 foot Penske truck was rented in which all the equipment was loaded. 3 people were required to bring the pontoons down the staircases. Rest of the equipment fit inside the large elevator. All the equipment fit inside the 16’ truck.

Figure 3: RoboDolf parts loaded in the back of a 16' Penske truck.

3.2 Initial Assembly

The vehicle was assembled on site using basic equipment transported to the field. This included a socket wrench set and a combination wrench set. The basic sea-cycle hull was first assembled. This was followed by the joining of the forward and after platform sections to create the platform assembly. The platform assembly was then bolted to the vehicle. Following this, the tower assembly was bolted to the platform.

The forward computer box was installed followed by the heavy battery box. All remaining wiring was routed and terminated into the appropriate locations.

Figure 4: Basic sea-cycle hull assembled and ready for the M-Platform (gray platform on left).

Figure 5: Battery box mounted at the stern. This was very heavy at 100 pounds and required multiple people to lift it in place.

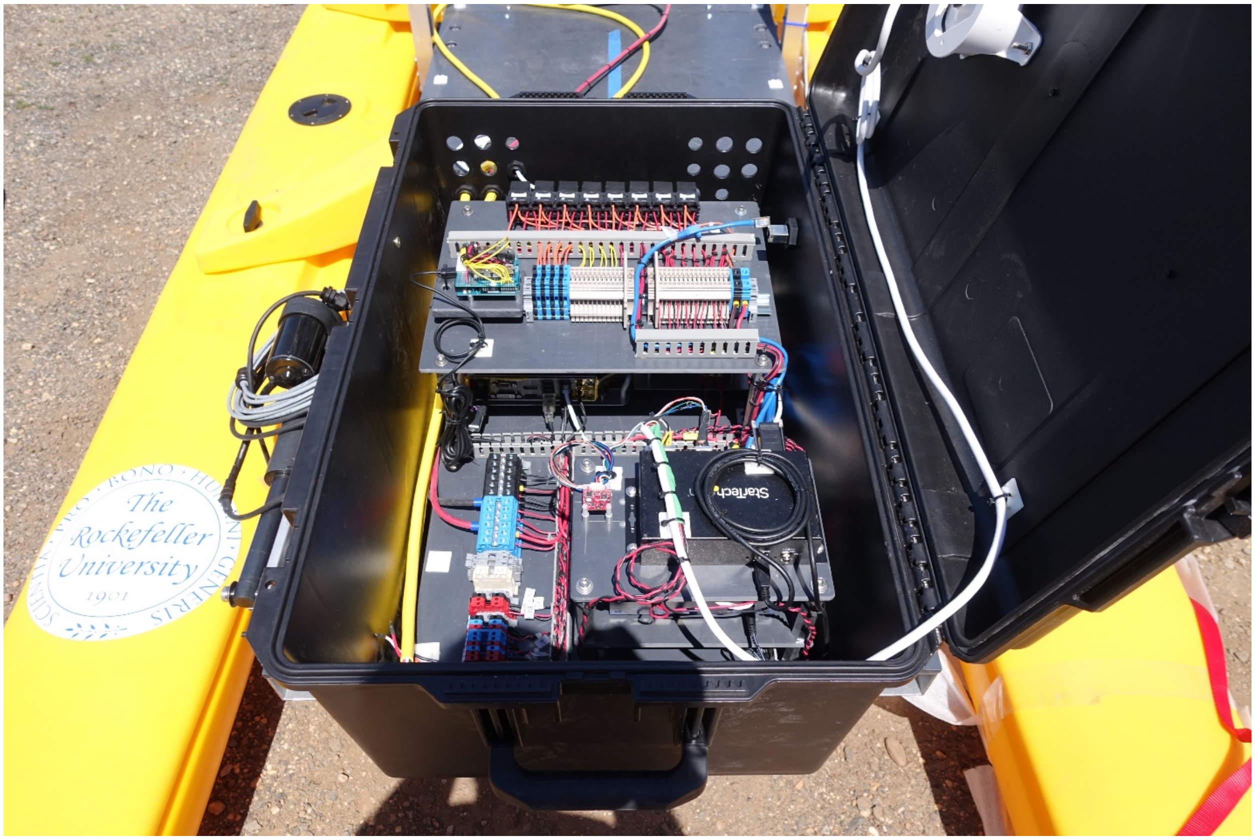

Figure 6: Manual wiring of the main computer box to all other peripheral systems.

The wiring process was difficult and time consuming because of two reasons. There were a number of systems that needed to be wired and the wiring method used was cord grip pass-throughs with bare leads to be terminated into screw terminal blocks. This required knowledge of where each wire was supposed to go, and introduced a degree of risk due to the possibility of incorrect wiring.

The entire assembly process took about 3.5 hours with the following breakdown:

Description	**Hours**
Loading the truck at the workshop	0.5
Unloading the truck at the beach	0.25
Mechanical assembly	1.25
Wiring	2
Systems check-out on shore	0.5
Disassembly and loading the truck on shore	1

Table 1: Time-table showing how long it took for the various test set-up operations.

3.3 Launching

Kayak dollies shown in Figure 7 were used to help launch the heavy RoboDolf down the beach into the water. This process worked well with 4 people. Two people up front lifted the bows and pushed while two people at each stern held the dollies in place.

Figure 7: Two kayak dollies, one per hull were used to launch the RoboDolf. They were mounted to the stern and strapped down.

Figure 8: Launching the RoboDolf with 4 people and the assistance of the dollies worked well.

3.4 Hydrostatics and Hydrodynamics

After launching the RoboDolf, it was evident that the vehicle was slightly stern-heavy. The heavy battery box was located aft led to this problem. The resulting nose-up pitch was minor, and addressed with having the operator sit on the forward computer box. This will be fixed for next test by having the battery box all the way forward along with the chassis being moved forward slightly.

Figure 9: Stern heavy trim with initial configuration. This will be fixed by moving the battery box forward.

Figure 10: Trim was improved during the field test by shifting the weight of the operator forward.

Apart from the trim issue the RoboDolf operated well and maneuvered within an acceptable performance envelope. A cruising speed of 4 knots was achieved with a high speed burst of 8 knots during favorable wind. It was noted that windage affected the RoboDolf's speed performance. Pitch and rolling rotations during operation were within acceptable stable sea-keeping limits.

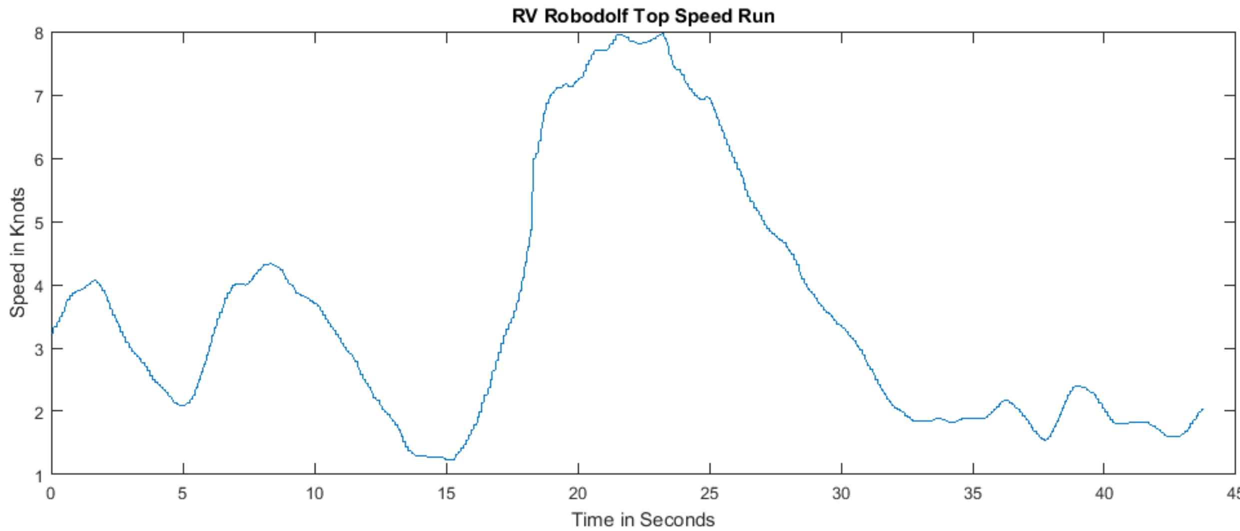

Figure 11: Brief top speed achieved at 8 knots.

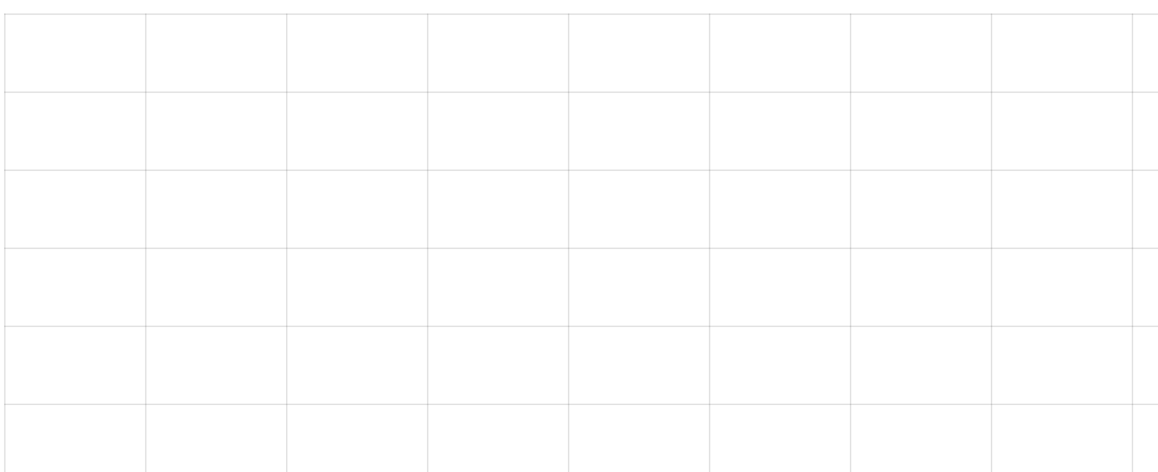

Figure 12: Pitch and Roll angles experienced during a run containing top speed transiting and maneuvering showing acceptable values.

3.5 Local Remote Operation

Local remote operation was the first operation mode tested. This involved the operator making use an on-board game controller to operate the vehicle. The controller contained an emergency stop and manual over-ride buttons and provided a means of doing Operator-In the - Loop tests while testing the autonomous operation of the RoboDolf.

3.6 Wireless Communications

The HSR is the RoboDolf's high speed wireless Link, consisting of an 802.11 2.4 GHz point-to-point link, which allows for a 100 Mbps connection to the vehicle's internal LAN. This link was tested and used to maintain remote connection to the RoboDolf while underway. The longest range tested was of 0.6 miles, shown as a yellow line in Figure 13. Signal started faltering past this range because we no longer had a line of sight due to trees. The HSR antenna, which was a directional dish antenna shown in Figure 14, was mounted at a low height of 3 feet and a better range performance can be achieved with a higher antenna placement.

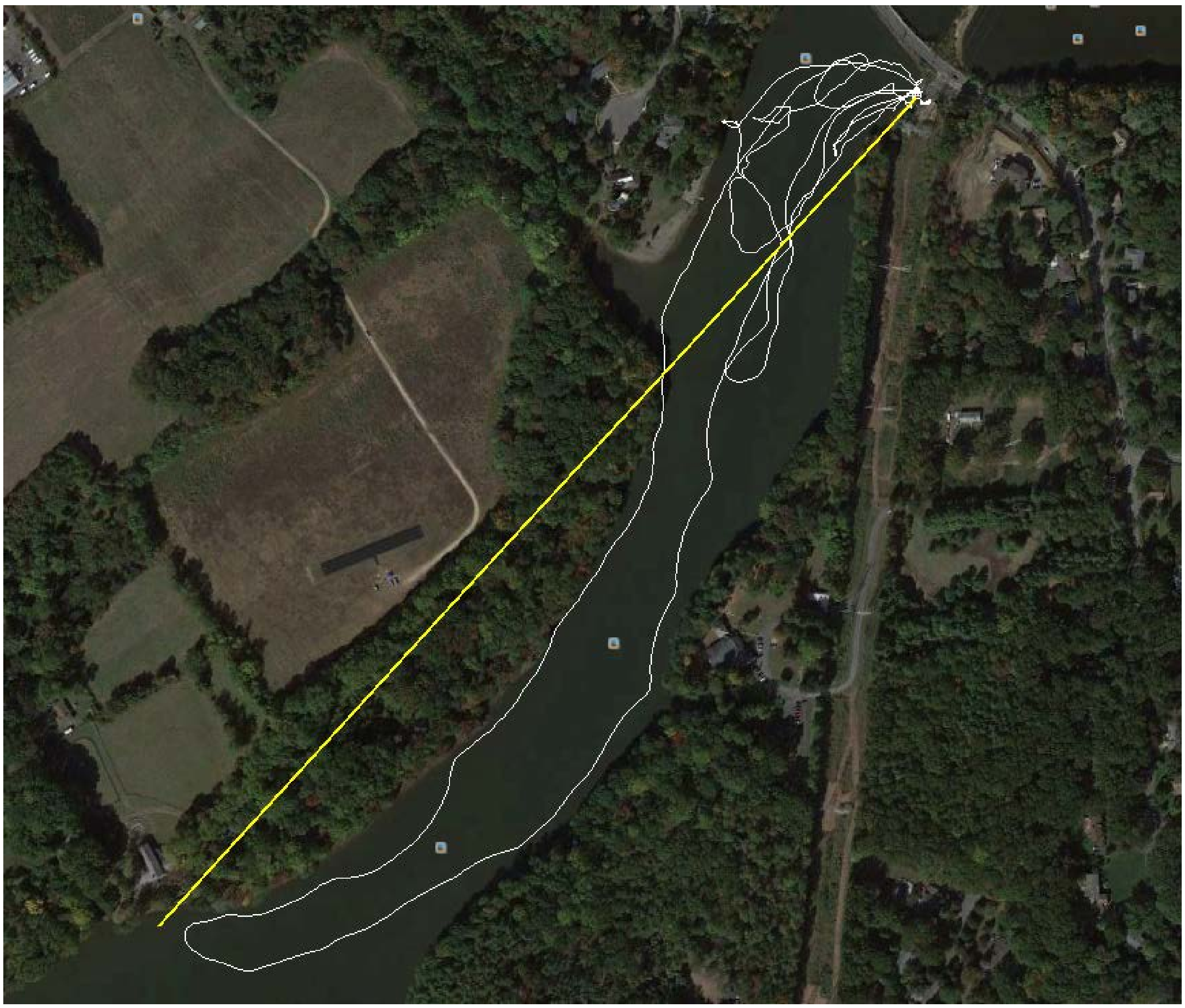

Figure 13: The white shows the track of the longest run done by the RoboDolf. Yellow is the straight line distance of 0.6 miles.

Figure 14: HSR Shore 2.4 GHz 22 dBi Dual Polarity MIMO Dish Antenna

The HSR antenna shown in Figure 14 worked well but was blown over by wind multiple times. The body of the antenna was slightly damaged but the damage was only superficial and did not impact performance.

The LSR was not tested in field test 1 due to some software issues and lack of test time.

3.7 AIP System

The AIP system was tested using round poles. The system deployed and retracted the poles properly but the round poles vibrated when the vehicle moved and one of the poles slipped out because it was not tightened properly. A redesign with hydrofoils instead of round poles was done after Field Test 1 which will reduce this issue and maintain a more stable AIP platform.

3.8 Instruments

3.8.1 Depth Transducer

The depth transducer was not functionally tested due to a sealing cable pass-through not being finished before this field test. However, it did pass the leak test.

3.8.2 GPS

The Garmin 19x HVS GPS unit worked well and provided adequate location data for the autonomous control loop to operate. The GPS antenna is housed inside of the MFB pelican case.

3.8.3 Axis Camera

An issue was encountered with the Axis PTZ camera where remote movement of the camera was stuck in certain axis. It is thought that this problem occurred during the bumpy truck ride. Apart from the pan/tilt/zoom functionality being stuck, the wireless video stream worked well and had no bandwidth issues with HSR link.

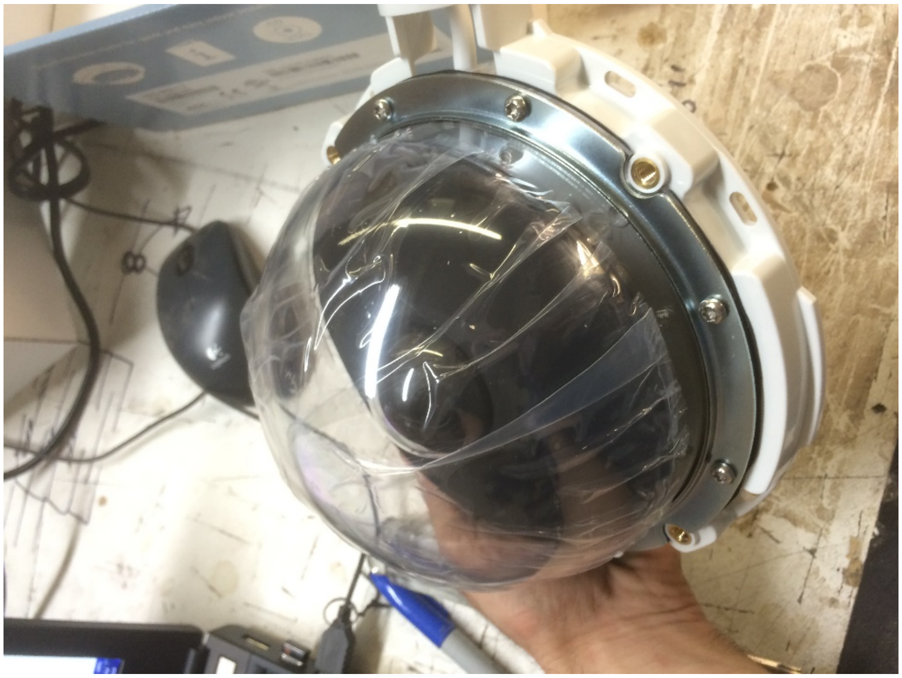

Figure 15: Axis M5013-V PTZ camera.

3.8.4 Compass

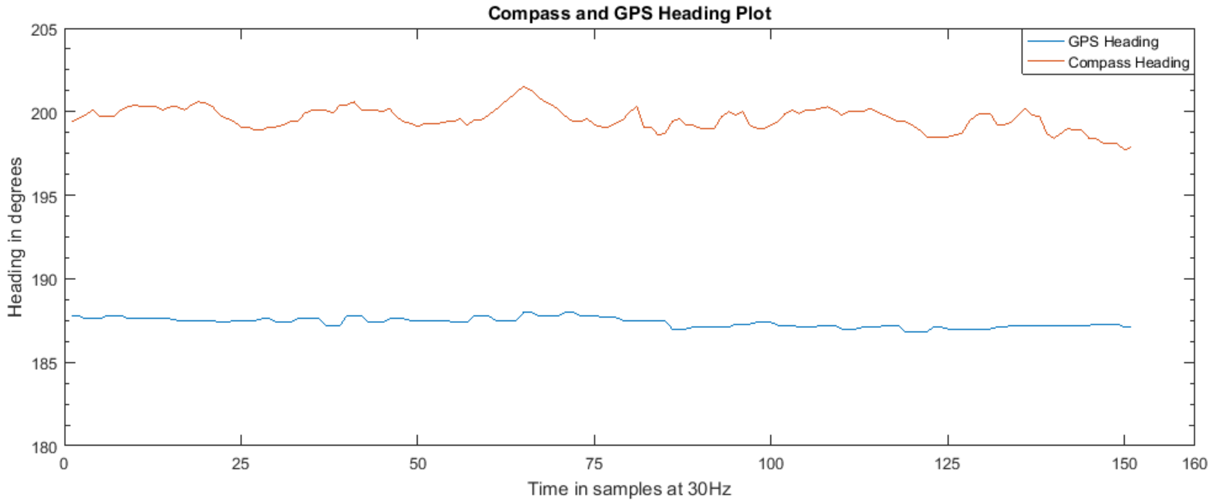

Figure 16: GPS Heading vs Magnetic Compass Heading showing magnetic declination.

The compass instrument used by the RoboDolf is an Oceanserver OS5000-S. This instrument is vital to the operation of the autonomous operation of the RoboDolf and worked well during testing. It was calibrated during operation and showed no faults or issues with magnetic interference of metallic objects near the sensor. A 12.2 degree magnetic offset was detected which agreed well with NOAA's listed magnetic declination of the area.

It is noted that the PID control loop was operated without the magnetic declination correction, but the system still worked as the control loop accounted for the error in heading using the GPS coordinates. Better tracking performance will be achieved with the simple offset correction.

3.9 Battery Power Performance

The RoboDolf contains a 200 Amp Hour 12 Volt nominal LiFePO4 battery pack. This battery pack comprised a significant portion of development effort of the RoboDolf project as it contains a number of electronic system for operation, monitoring and safety. This pack is made up of 8 individual LiFeMnPO4 cells whose temperature and voltage are monitored and managed throughout operation.

During the first field test all battery systems operated well within specifications and there were no issues.

3.9.1 Power Draw

With only the basic systems running and no propulsion, the draw was 4 amps. At full power to both thrusters the draw was 75 amps. There were no fuse issues with the fuse configuration selected for the Field Test 1. At the end of the field test, the battery pack was at 45% capacity.

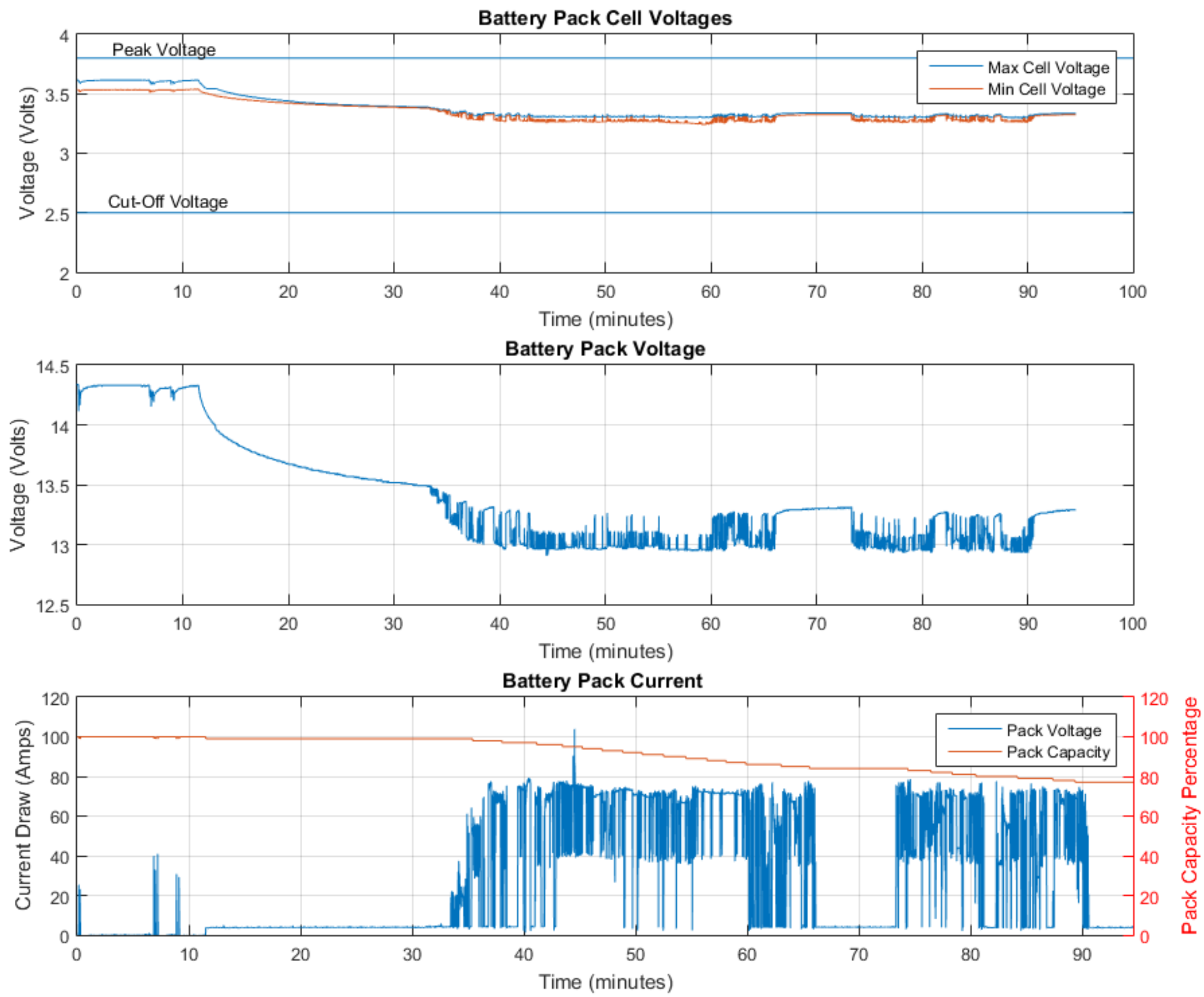

Figure 17: Plot showing the pack information throughout a long run. The fluctuations in the current draw is due to changing throttle commands.

3.10 Thermal Performance

Field Test 1 was conducted during a hot sunny day during which temperatures went into the low 90s.

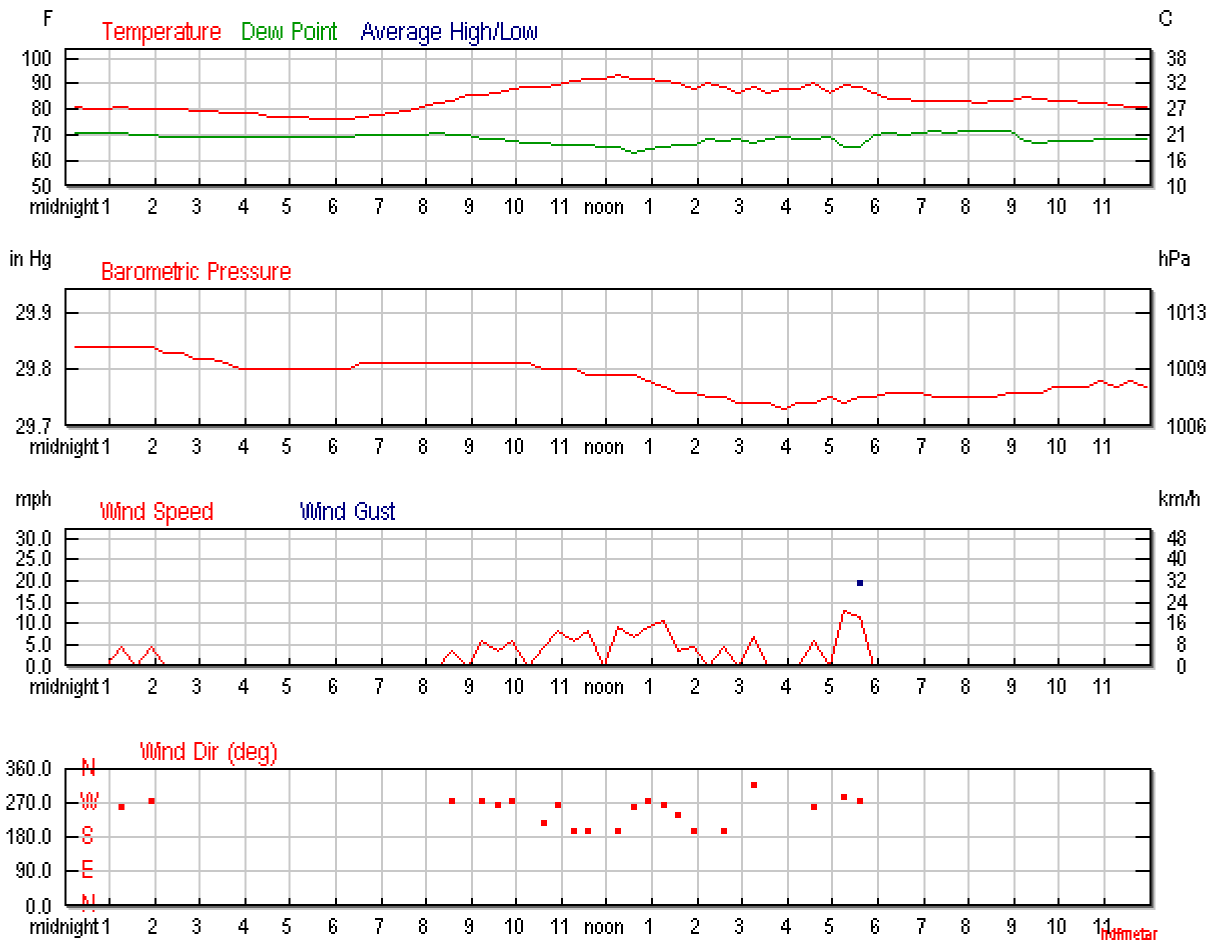

Figure 18: Weather for the testing location during that day. Source: https://www.wunderground.com historical weather data.

All electrical systems operated within their thermal limits throughout the day of operation. The batteries did not get very hot and operated at around 37 ^{o}C. The individual cells are rated to discharge operation up to 65 ^{o}C. This operation was with no addition cooling and with the boxes closed.

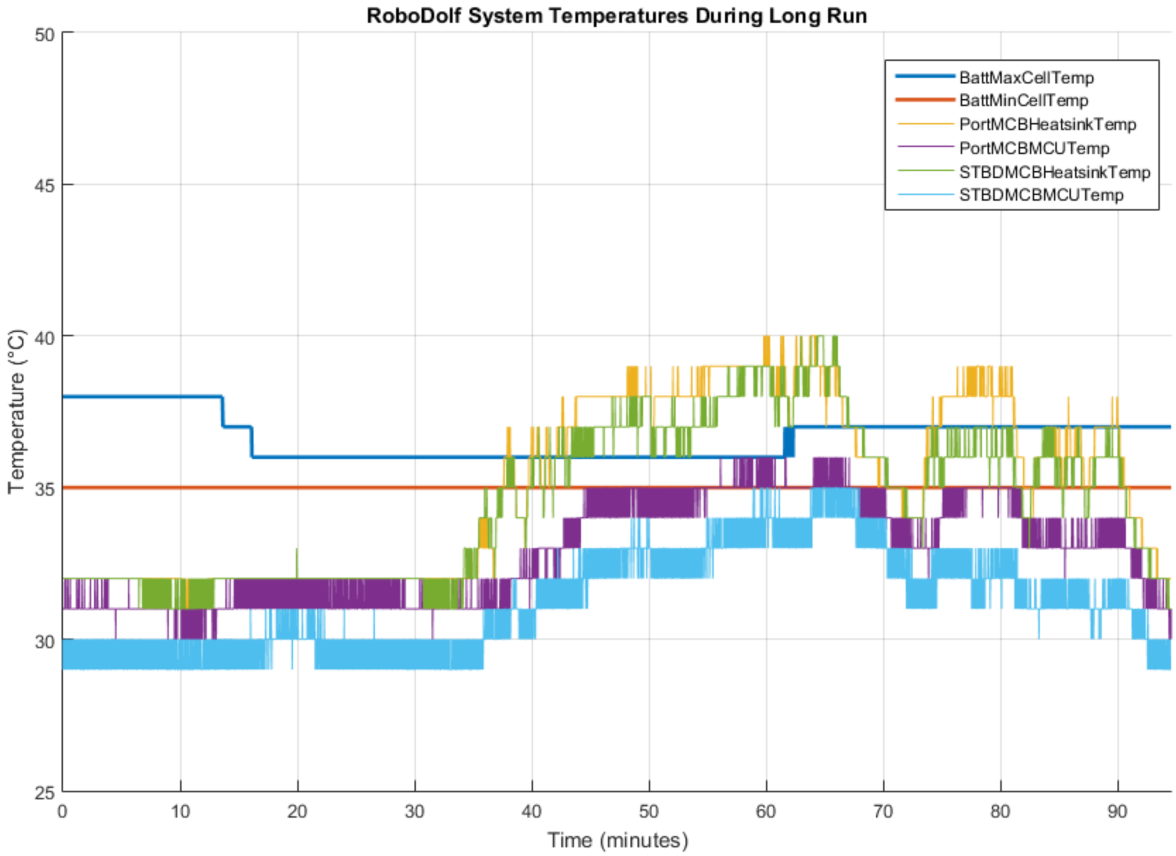

Figure 19: Temperature information from the various temperature sensors onboard the RoboDolf.

The temperature data shown in Figure 19 comes from sensors inside of the battery box and both port and starboard motor controller boxes (these are the silver boxes at the stern of each pontoon). Unfortunately there was no temperature sensor inside the main computer box but the computer temperatures were monitored periodically and operated under 50 ^{o}C. The computer did not over-heat at any point during the run.

3.11 Differential Thrust Rudder Control

The RoboDolf automatically steers using a differential thrust rudder scheme. This rudder control is used in conjunction with the desired throttle to set the power command to the individual port and starboard thrusters.

A rudder multiplier is calculated for each thruster using a mapping function. The mapping function used in Field Test 1 is shown in Figure 20.

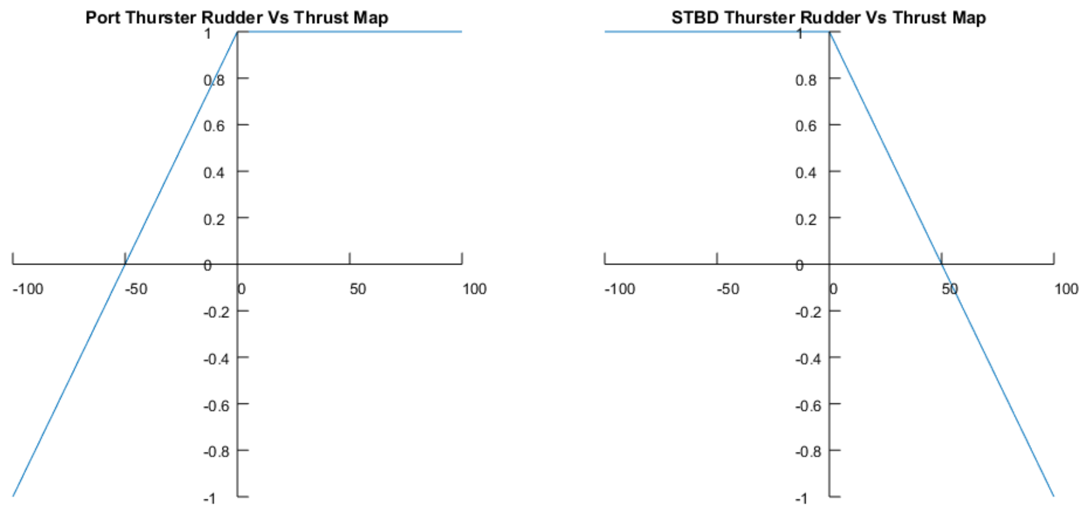

Figure 20: Thrust mapping functions used in Field Test 1. X axis is rudder and Y is thrust. X axis: -100 is full to port, 100 full to STBD. Y axis: 1 is all ahead and -1 is all astern.

It was found that the original thrust mapping used in Field Test 1 was too aggressive and gave hard turning with a slight turn input on the control stick. It was decided to tweak the thrust mapping based on this operator feedback. A tweaked non-linear mapping was implemented after the field test shown in Figure 21 with possible curves in red and blue. This mapping can be further tweaked during operation.

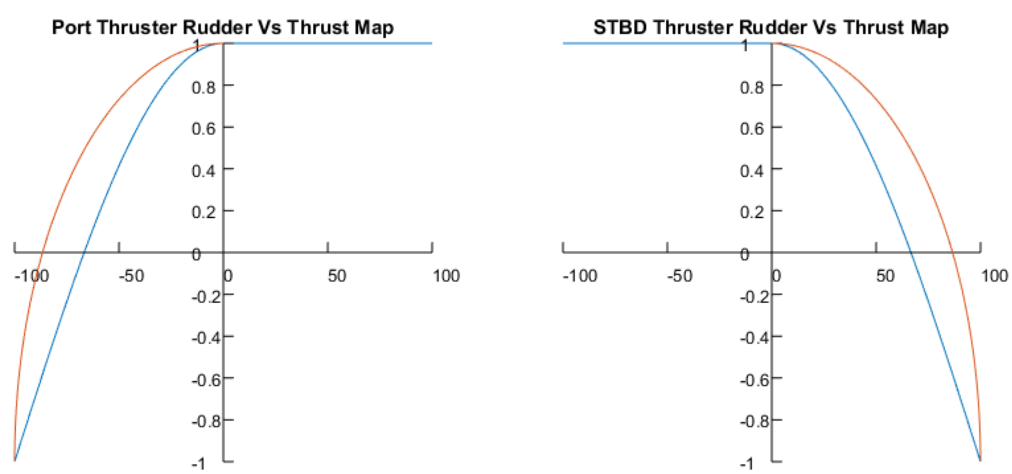

Figure 21: Non-linear thrust mapping which is aimed to give better handling during operator remote control.

3.12 Heading PID Control

Following remote operation runs, the Heading PID Controller was tested. This controller is the slave controller that outputs a rudder command to maintain a heading.

The controller was tested by issuing heading commands and monitoring the performance. After a few gain setting iterations, a gain set was selected that allowed the vehicle to maintain heading.

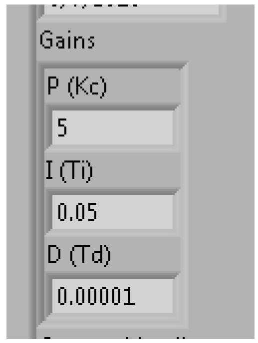

Figure 22: Gains that were selected during Field Test 1 following experimentation.

3.13 Mission Run

Following the heading controller validation, the mission controller was tested. A mission containing waypoints and AIP operation commands was uploaded wirelessly to the vehicle from shore. During the first test a GPS coordinate mapping error was found and fixed. On the second go, the RoboDolf followed the mission successfully and returned to shore on under autonomous control. Show in is the recorded vehicle track as it went from waypoint to waypoint, ultimately reaching shore.

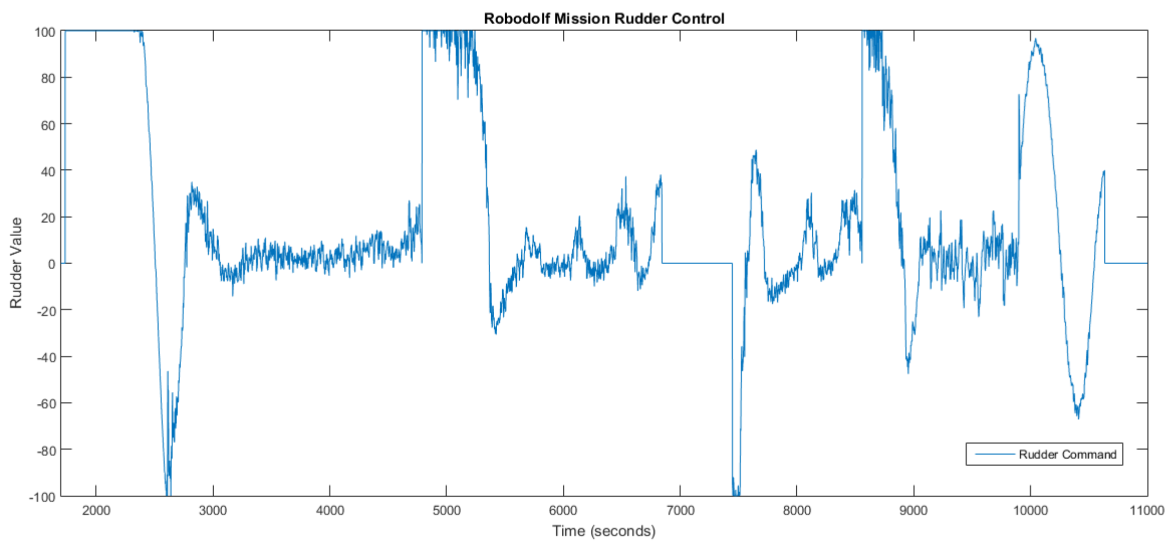

Figure 23: Autonomous rudder control during mission.

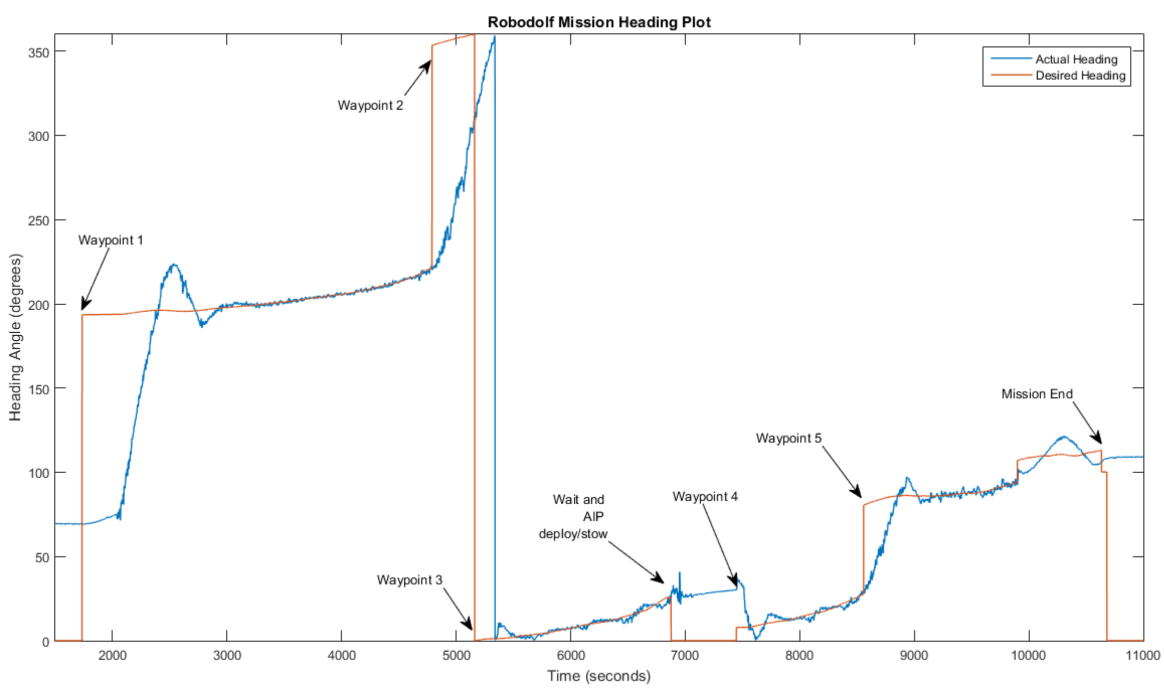

Figure 24: PID controlled heading during mission run.

Show in Figure 24 is the heading track showing commanded vs actual heading while the vehicle followed the mission script.

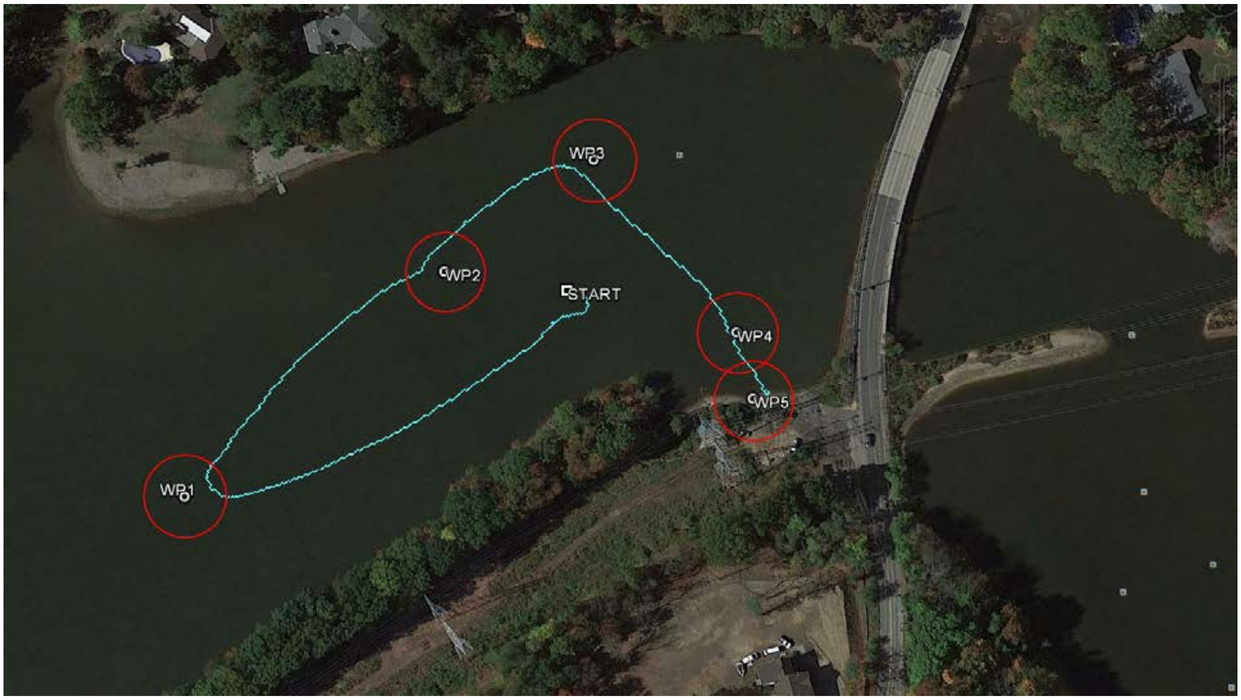

Figure 25: RoboDolf Mission script track. The circles indicate waypoints with a maximum radius of 15 meters.

Figure 26: Vehicle operating in mission mode.

3.14 Disassembly

Disassembly took less time than the initial assembly. The tower was disassembled from the chassis. The chassis was broken up into the forward and aft sections and the BTB and MFB were left attached to their sections. This minimized the wiring work.

Figure 27: The truck packed up and ready to return to the shop.

4 Conclusion

The first field test for the RoboDolf project provided a great of amount of data on the operation of the vehicle and autonomous operation was achieved. All major systems were tested with the exception of shore-remote operation through the LSR. Sammut Tech LLC thanks Dr. Magnasco and Rockefeller University for the opportunity to work on this project, and also thanks Dimitrious and Keith for giving up a whole day to help us out.

Figure 28: The team