Team Redhawk Report AAVC 2015

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*Abstract*—The following is a report detailing Miami University’s entry vehicle in the Autonomous Aerial Vehicle Competition of 2015. It details the algorithms

# Team Members

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Iami’s team consists of three members: Nick Contini, John Thomas, and Braden Campbell. Work was divided as described. Nick Contini was the primary programmer for any image processing, as well as the primary contributor to the starting code for the laser rangefinder and sonar modules. He also contributed to PWM code to control the flight controller, assisted in quadcopter construction, and was founder of the project. John Thomas was the primary contributor to PWM code and the Raspberry Pi expert. He also 3D printed any extra models that were needed as parts, and assisted in algorithm development. Braden Campbell was in charge of maintaining code and documenting the project.

# List OF Parts

* Raspberry Pi Model B – $44.95
* Arduino Mega ADK - $59.95
* Ardupilot 2.6 - $159.99
* ZIPPY Flightmax 3000mAh 3S1P 20C – $15.71
* 3DR DIY Quad Kit 2014 - $550.00



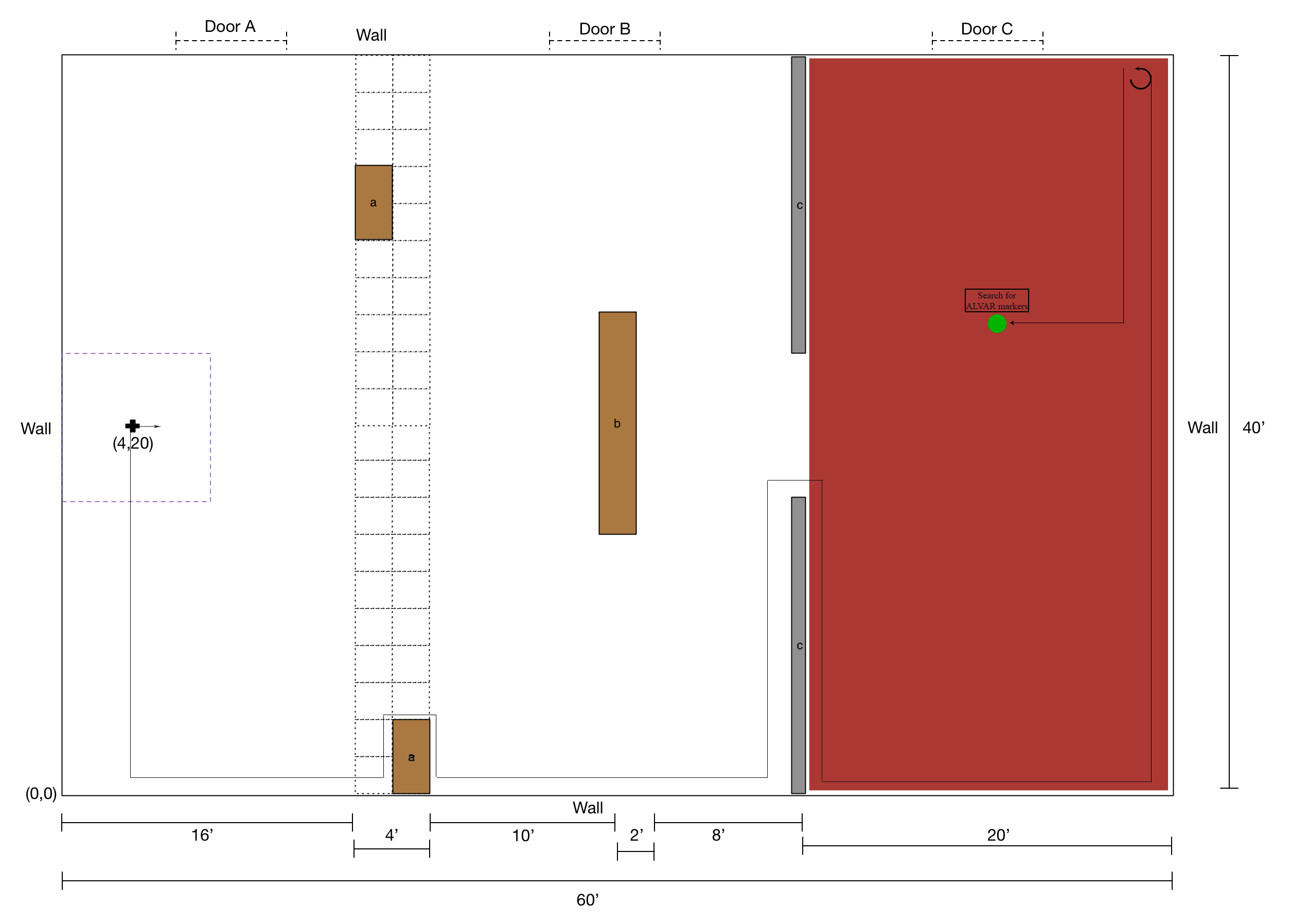
* HC-SR04 Sonar Modules (4) – $17.98
* [UT390B](http://dx.com/p/uni-t-ut390b-45m-laser-distance-meter-178482?Utm_rid=18166238&Utm_source=affiliate) Laser Rangefinder - $52.99
* Raspberry Pi Camera Board – $29.95
* Ourlink USB Wifi Dongle – $12.95
* 3D Printed Mounts - $3.00

# Search Algorithm

The search algorithm allows the vehicle to be as simple as possible. The vehicle starts by facing the second room. It hugs the right wall, making sure to shift left anytime an obstacle is sensed in from of it. It recognizes that it is in the second room once senses a wall on its left after drifting left for some time. It then rotates 180° and then starts drifting to its left. It begins taking pictures in order to find the ball. Once the ball is found, the quadcopter hovers over the ball and begins searching for the ALVAR markers.

Above: The input (left) and output (right) into the object detection algorithm

Above: a diagram showing the search algorithm implemented in a representation of the competition field



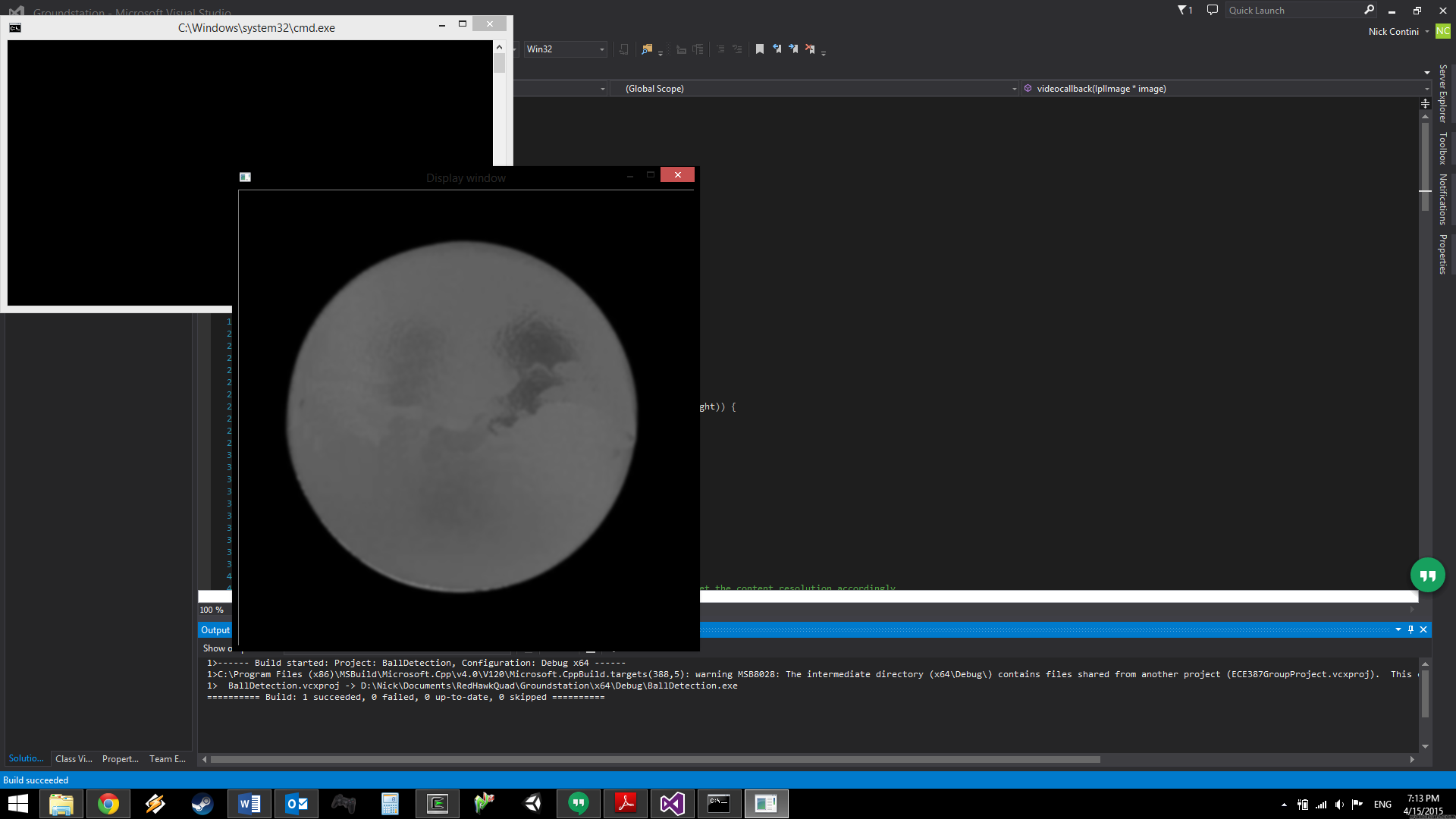
Once an ALVAR is located, the vehicle will measure the distance using the laser rangefinder. Once two ALVARS are found, the quadcopter will use the coordinates of the ALVARS as well as a system of distance formulas to find the ball’s coordinates:

of ALVAR 1

of ALVAR 2

of the quadcopter/ball

# Image Processing

The target identification run by the ground station is relatively simple. Using the OpenCV C++ library, the image sent from the quadcopter is split from one three-channel image to three one-channel images, so that the program can manipulate the red, green, and blue channels independently. Since the object the vehicle is searching for is green, the program’s objective is to block all color but pure green. To accomplish this, the program averages the red and blue channels and subtract the result from the green channel. This effectively removes all white and near white pixels and dampens blue and red pixels. The program then uses OpenCV’s Hough Circles feature to locate a circle. If a circle is found, the vehicle begins to search the room for ALVAR markers.

# Safety

In order to safely disarm the quadcopter in the event of a failure of the system two disarm mechanisms have been added. First, a software disarm feature has been added into the control algorithm that, when the groundstation sends a kill command, will cause the quadcopter to enter into a landing mode. From here the quadcopter will land and be safe to recover. The second kill switch will be a manual switch on the flight controller that when switched will also initiate the landing procedure.

To test the safety system, a controlled environment was set up where the quadcopter would navigate part of the course and the disarm mechanisms were tested. For the software disarm feature the quadcopter was allowed to follow a wall on it right side and when the operator was ready the kill command was sent from the groundstation through wireless communication and the quadcopter initiated landing. This same test was performed with the manual kill switch located on the flight controller to make sure both mechanisms work appropriately.

# Ground Station

Communication with the quadcopter is predominately done through SSH protocol over a private and secure WiFi network. Initially the takeoff script will be run from the ground station to begin the flight sequence and from then on the quadcopter will operate on its own. In the event of a catastrophic failure the operator of the ground station will be able to send a kill command over HTTP protocol to stop the quadcopter and initiate the landing sequence. When the ball has been found the Raspberry Pi will use the SCP protocol to send the image of the ball to the ground station for further processing.

Once the image of the ball has been received, the ground station will do further processing to isolate the ball in the image received. From here, commands will be sent to the quadcopter over SSH to position the quadcopter over the ball and begin searching for the ALVAR markers. Once again, images will be sent to the ground station in order to detect the ALVAR markers. For each marker found, the quadcopter will send the coordinates corresponding to each marker.

# Design

Since the quadcopter itself was purchased as a package the main design of the frame was not changed much. The changes that were made are the addition of a second platform to hold the Raspberry Pi, four 3D printed brackets to hold the sonar modules, changing many of the nylon screws out for metal ones, and securing the laser range finder to the frame.

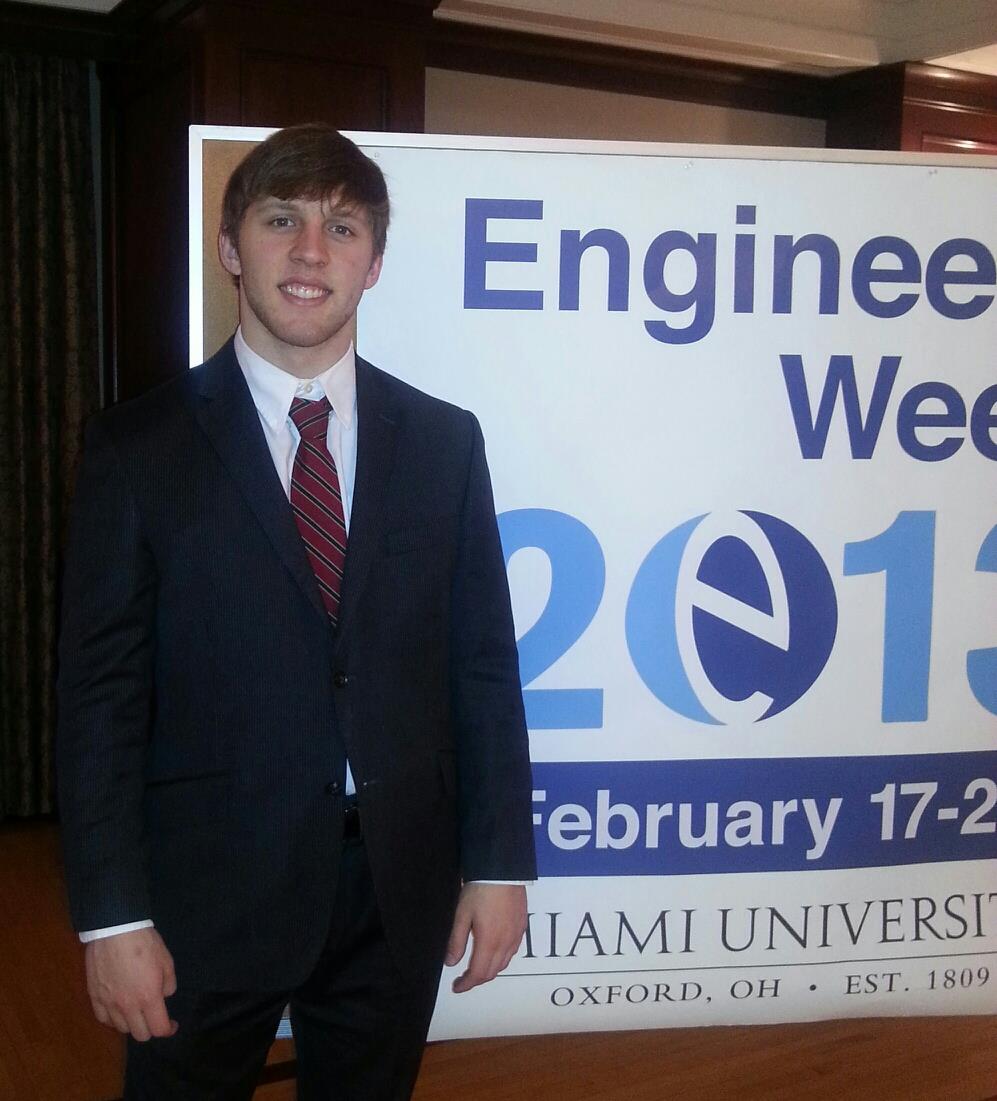
Sonar modules are used as the main object avoidance device due to their range and energy efficiency. Adding the four sonar modules towards the center on each of the sides of the center body of the quadcopter was done as it is seen as the most logical position to be placed in. Having the sonars closer to the main body would give the pulse a greater range left to right as the signal travels out and helps to make sure that closer objects are still seen. Initially it was thought that the downdraft of the propellers may cause interference with the sonars but after tests were run it was evident that this was not the case.

Using the laser range finder (LRF) as the main device to tell the distance to the alvar markers ensures that a very accurate measurement is taken so determining the coordinate system is as accurate as possible. Placing the LRF facing the front of the quadcopter was done because of the camera also facing the front. Using image processing on the images returned of the alvar markers, the program will be able to determine if the laser range finder is accurately pointing towards the alvar marker and adjust if the need arises.

Navigating the rooms by following the right wall was seen as the simplest and most effective way to navigate the rooms. The quadcopter navigates facing the direction of the second room at all times so that the quadcopter only has to focus on going forward. In the case where an object should be found in its way in the first room, the quadcopter will be able to navigate around it since all boxes are known to be at least a 5 feet apart, plenty of room for the quadcopter to navigate through. When the quadcopter reaches a corner with a wall in front of it and to its left. After detecting a wall after shifting left for some time, the quadcopter knows it is in the room with the ball and the search can begin for the ALVAR markers and ball.

Searching for the ball first from the corner of the room is the stronger option as the ALVAR markers should be easier to detect from above the position of the ball. After locating the ALVAR markers from this position and measuring their distances from the ball a system of equations can be used to determine the ball’s position within the room. From this the local coordinate system of the room can be determined.

**Nick Contini** A Junior Computer Engineering Undergraduate from Miami University. As original founder of the project, he started work on the Redhawk quadcopter in the summer of 2014. He has done numerous other projects including guitar pedals, CPU design, and game design. He has consistently made the President’s list and has been elected for Top Engineer and well as Undergraduate Summer Scholar. This summer he will work for Synchrony Financial’s IT department as part of their Business Leadership program. A December 2015 graduate, Nick is interested in parallel processing, game design, hardware design, and digital signal processing.



**John H. Thomas** was born in Bedford, Ohio, in 1992. He received the B.S. and M.S. degrees in computer engineering from the Miami University, in 2015.

From 2001 to 2004, he was a Research Assistant with the Princeton Plasma Physics Laboratory. Since 2009, he has been an Assistant Professor with the Mechanical Engineering Department, Texas A&M University, College Station. He is the author of three books, more than 150 articles, and more than 70 inventions. His research interests include high-pressure and high-density nonthermal plasma discharge processes and applications, microscale plasma discharges, discharges in liquids, spectroscopic diagnostics, plasma propulsion, and innovation plasma applications. He is an Associate Editor of the journal *Earth*, *Moon*, *Planets*, and holds two patents.