# Robotics Challenge: Utilization of SLAM for Autonomous 3D Robotic Mapping with an Archimedes Screw Driven All-Terrain Vehicle

**Josh Fender and Cody Helms**
UNIVERSITY OF NORTHERN COLORADO, DEPARTMENT OF PHYSICS AND ASTRONOMY
FACULTY ADVISORS: DR. M. SEMAK AND DR. C. GALOVICH

## Abstract

The primary goal of this research project is the successful implementation of a Simultaneous Localization and Mapping (SLAM) system in conjunction with an Archimedes screw drivetrain to create a fully autonomous, all-terrain robot. It will compete with robots developed by other higher education institutions from around the state of Colorado on an obstacle course chosen to replicate the same environment a rover might encounter on the surface of Mars.

The same SLAM systems we are developing on a small scale are becoming more commonplace with the increasing prevalence of self-driving cars. These systems require both a method of "seeing" their surroundings and of responding to and interacting with their environments.

Along with the implementation of the SLAM system, we are developing a drivetrain using principles similar to those governing an Archimedes screw. The screw drive consists of a hollow cylinder with a helix wrapped around it. This drivetrain allows the robot to move over numerous types of terrain such as sand, ice, mud, grass, water, etc.

Our design approach will be put to the test at the Colorado Space Grant Consortium's annual Robotics Challenge held on April 14, 2018, at Great Sand Dunes National Park in Mosca, Colorado. During the competition, the robot will be tasked with locating a radio beacon placed at the center of an obstacle course consisting of various environments that the robot might encounter on the surface of Mars.

Figure 1. Shown above is a 3D rendering of *Patricia 5*. This is the 5th prototype of the robot designed after significant testing of previous versions.

## Acknowledgments

Many thanks to: Chris Koehler, Brian Sanders, the rest of the Colorado Space Grant Consortium team, NASA, and our friends and family for their support with this project.

## SLAM

SLAM is a method by which a sensor identifies its own position and orientation relative to its surroundings while simultaneously generating a real-time map of its environment. There are countless types of sensors, including ultrasonic, Light Detection and Ranging (LIDAR), and visual cameras, that can be used with various algorithms to create a SLAM system.

For this project, the robot utilized existing architecture from another robot, called a "Turtlebot," which uses a LIDAR sensor controlled by a Raspberry Pi microcontroller loaded with a Linux-based Robot Operating System (ROS). The LIDAR sensor sends out infrared laser pulses and measures the reflections to determine the range to various features. A servo is used with the LIDAR sensor to provide directional information to the range data. This information is fed into ROS, which uses the data to generate a two-dimensional map of the robot's environment. See Figure 2.

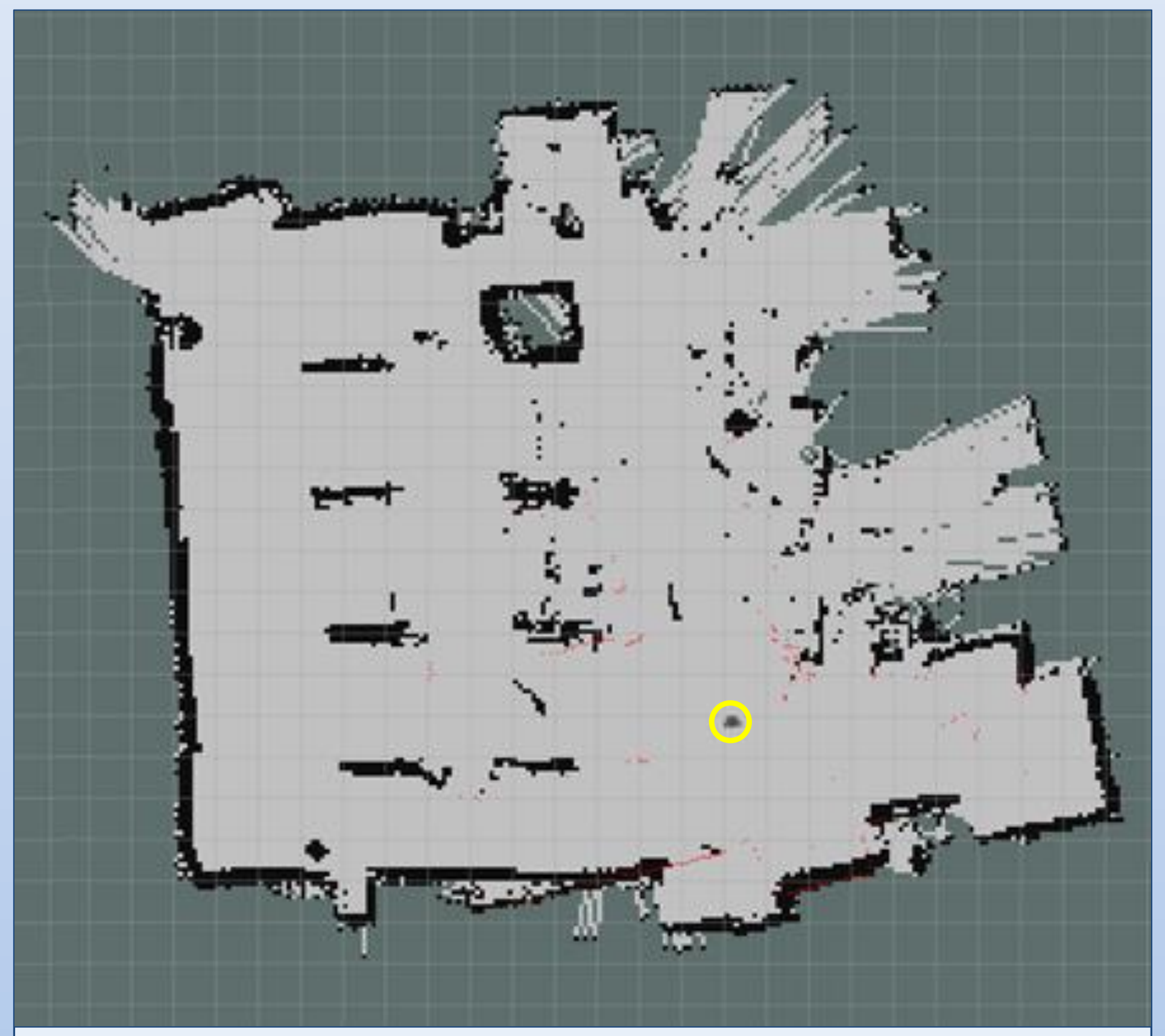

Figure 2. Shown here is a 2D map of the Kodak Optics Laboratory in Ross Hall. This is what the robot "sees" using its ROS framework. The yellow circle identifies the location of the robot.

ROS then identifies features that would prevent the passage of the robot so that it may navigate around them. As the robot moves through the course, the map is updated in real-time. Unique features on the map are used to update the robot's position as it moves.

## Logic Flow

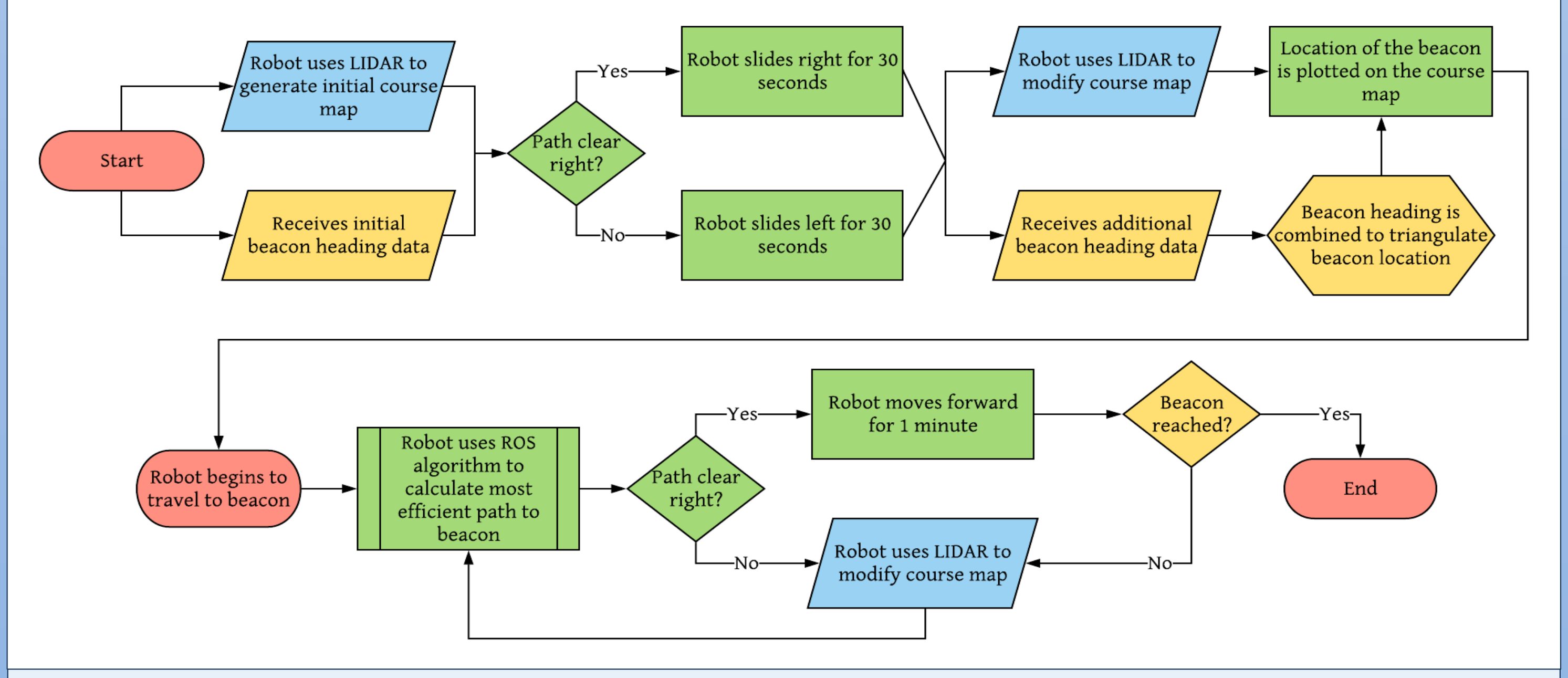

Figure 3. This is a diagram of the functional logic flow for the operations of the robot. Red nodes represent key transitions in the flow, blue nodes represent SLAM operations, yellow nodes represent beacon radio operations, and green nodes represent movement commands or the integration of SLAM and beacon operations.

## Screw Drive

Ancient Greek inventor and scientist Archimedes is thought to have developed a method of raising water from lower areas like a well or the hold of a ship. His machine consisted of a cylindrical pipe which enclosed a rotating helix. This same type of machine is used today in grain elevators to transfer grain from trucks and storage silos.

This machine can be used in propelling a vehicle across various types of terrain by removing the cylindrical enclosure. A rotating pair of these screws with the helixes wound in opposite directions (see Figure 4) can push a vehicle forward. When travelling on a pliable surface, the helixes are able to "bite in" and gain traction, with the weight of the vehicle determining the depth of the "bite." Consequently, this type of drivetrain is not suited for smooth, hard surfaces. In addition, by increasing the size of the central shaft of the helix and keeping it hollow, the screws can now be used like pontoons on a boat. This allows the vehicle to traverse water, marshes, and deep snow that wheeled or tracked vehicles cannot.

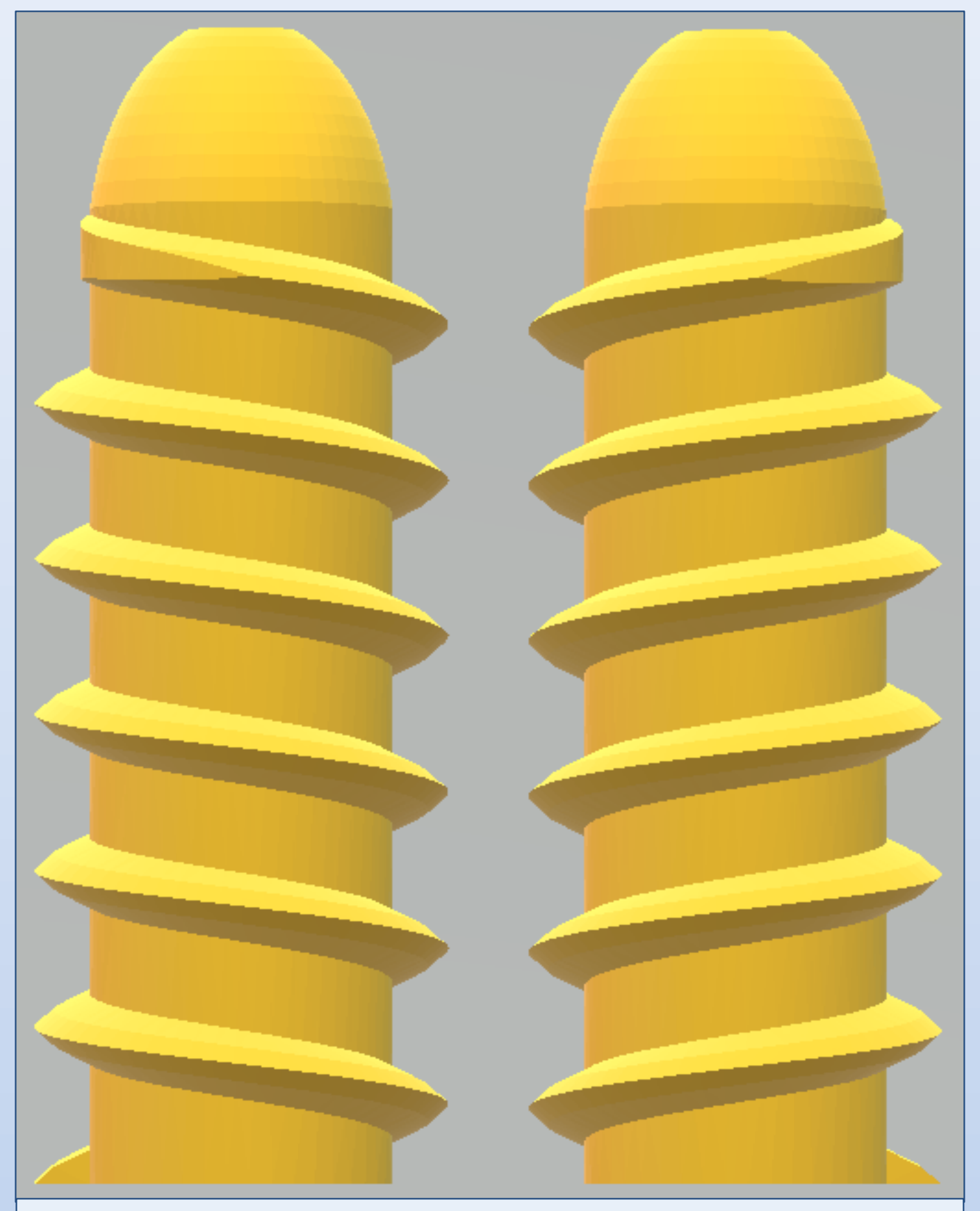

Figure 4. Shown is a 3D rendering of a pair of drive screws with helixes wound in opposite directions.

## Testing

The final testing for this project will occur on April 14, 2018, at Great Sand Dunes National Park near Mosca, Colorado. A circular obstacle course approximately 100 feet in diameter will be laid out with a radio beacon placed at the center. The circle will be divided into six courses and each will consist of different types of terrain: deep sand, hard dirt, inclined, rocky, etc. See Figure 5. The robot must navigate each of the sectors.

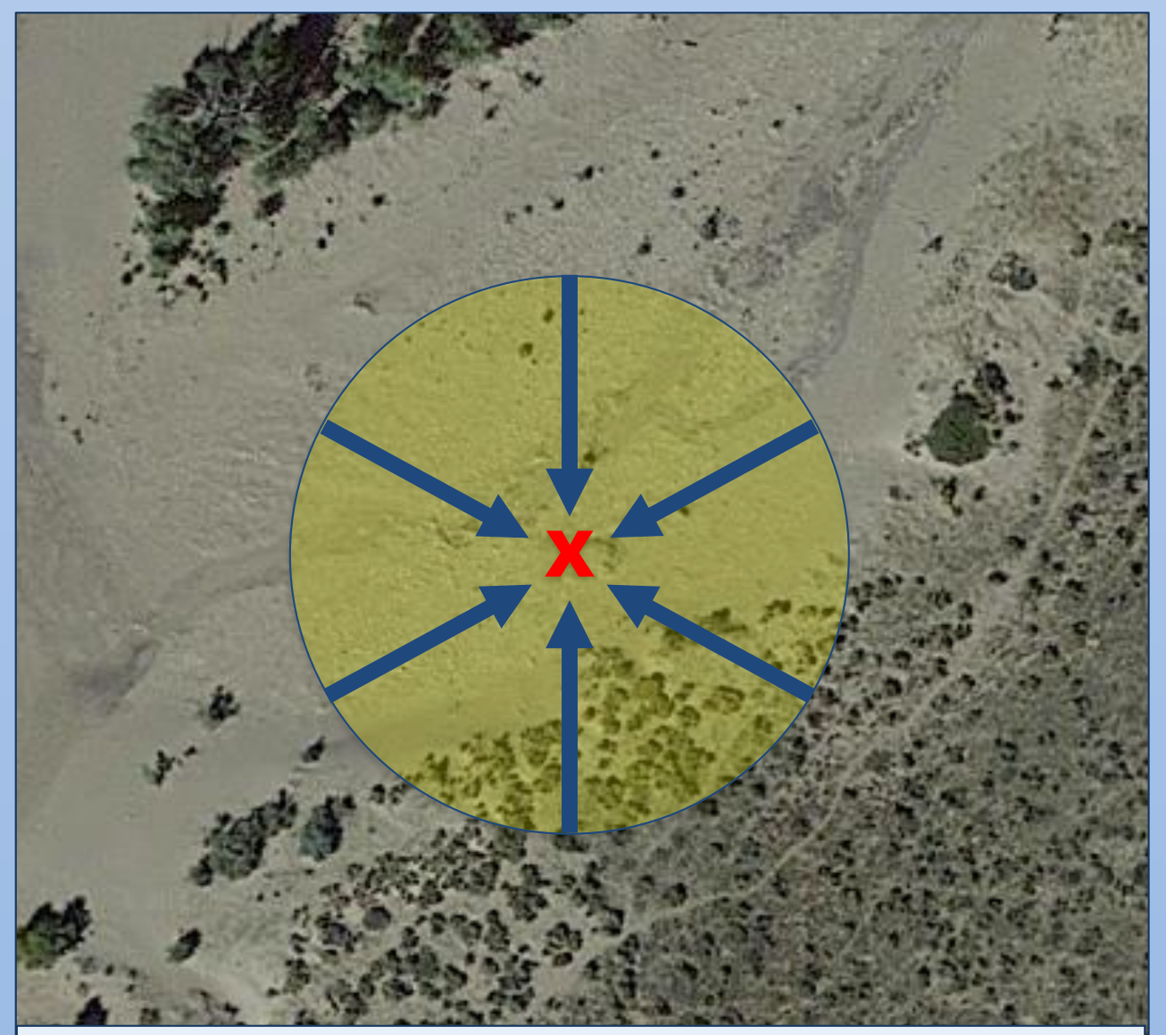

Figure 5. Pictured above is the obstacle course. The red x represents the location of the beacon and the blue arrows indicate the six sectors.

The beacon will consist of a directional antenna and a compass, both controlled by an Arduino microcontroller. It will continuously rotate a full 360 degrees while broadcasting the heading that the antenna is facing. The objective is for the robot to navigate to the beacon without any human assistance.

In addition to this obstacle course, the robot must autonomously transition into and traverse a pool of water.