# Project Plan Rev. 2

MAY14-08     3D LIDAR

**Members**

Nicolas Cabeen – Project Leader

Xiang "Peter" Wang – Software

Todd Wegter – Communications & Mechanical

Eric VanDenover – Electrical

**Advisor**

Koray Celik

# Table of Contents

I. **Nomenclature** ........ 2
II. **Problem/Need Statement** ........ 2
III. **Concept Sketch** ........ 3
IV. **System Block Diagram** ........ 3
V. **Software Block Diagram** ........ 4
VI. **System Description** ........ 4
VII. **Operating Environment** ........ 5
VIII. **User Interface Description** ........ 5
IX. **Functional Requirements** ........ 5
X. **Non-Functional Requirements** ........ 6
XI. **Market/Literature Survey** ........ 6
XII. **Deliverables** ........ 7
XIII. **Work Plan** ........ 7
Work Breakdown Structure
491 Project Schedule
Resource Requirements
Risks

# Nomenclature

Laser - a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation

LIDAR - term combining 'light' and 'radar' - device which measures distance by illuminating a target with a laser and analyzing the reflected light

2D LIDAR - a LIDAR which performs a sweeping scan with the laser along one axis to measure the distances along that axis - this gives two dimensional data

3D LIDAR - a LIDAR which performs a sweeping scan with the laser along two axes to measure the distances of a two dimensional area - this gives three dimensional data

Pointcloud - a set of data points in some coordinate system

PWM - Pulse Width Modulation, a signal modulation technique that alters the duration of the pulse to encode information

ROS - Robot Operating System, an open source software framework for robot software development

RS-422 - high speed serial bus necessary for communicating the vast amount of data a LIDAR creates

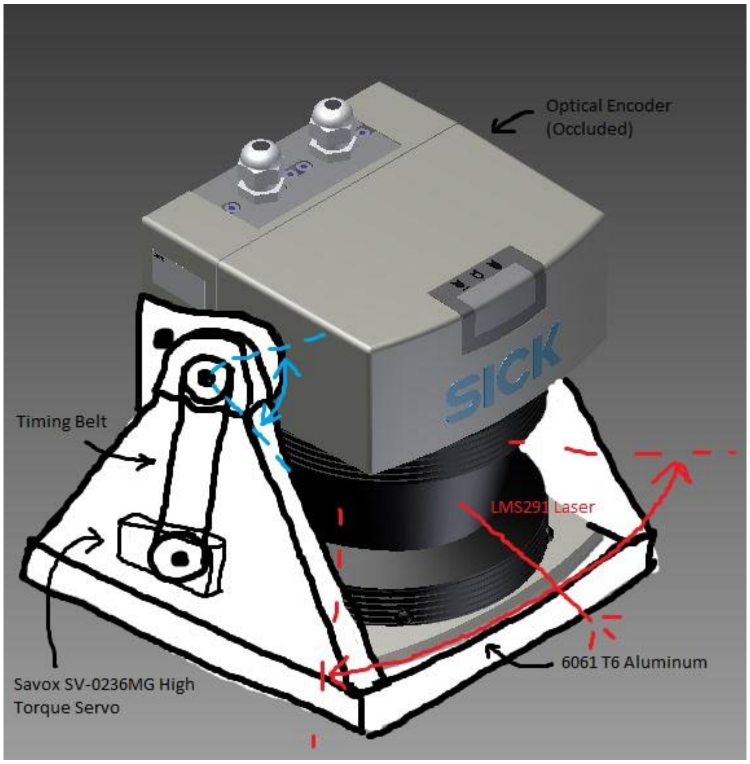
Servo - a DC motor and transmission which turns to a specific angle given a PWM signal

Stepper Motor - a brushless motor which is controlled through 'step' commands to its electromagnetic coils

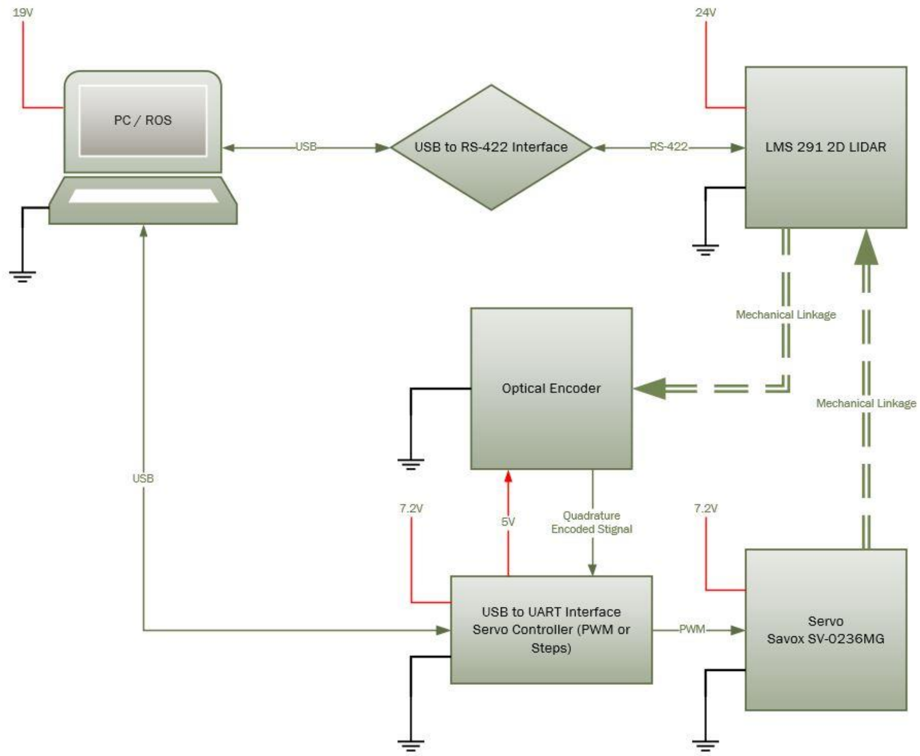
# Problem/Need Statement

3D LIDAR is a very expensive piece of technology which can cost upwards of $100,000. This cost is too substantial to use this sensor in many applications. However, a 3D LIDAR is the best device for accurate and precise volumetric scanning. We would like to make this device available at a lower cost and reach out to the robotic community by making it more accessible. Schools, researchers, and the Iowa State Lunabotics Team could all benefit from having this technology available to them. The Lunabotics team currently needs a sensor that can detect objects in extreme environments.

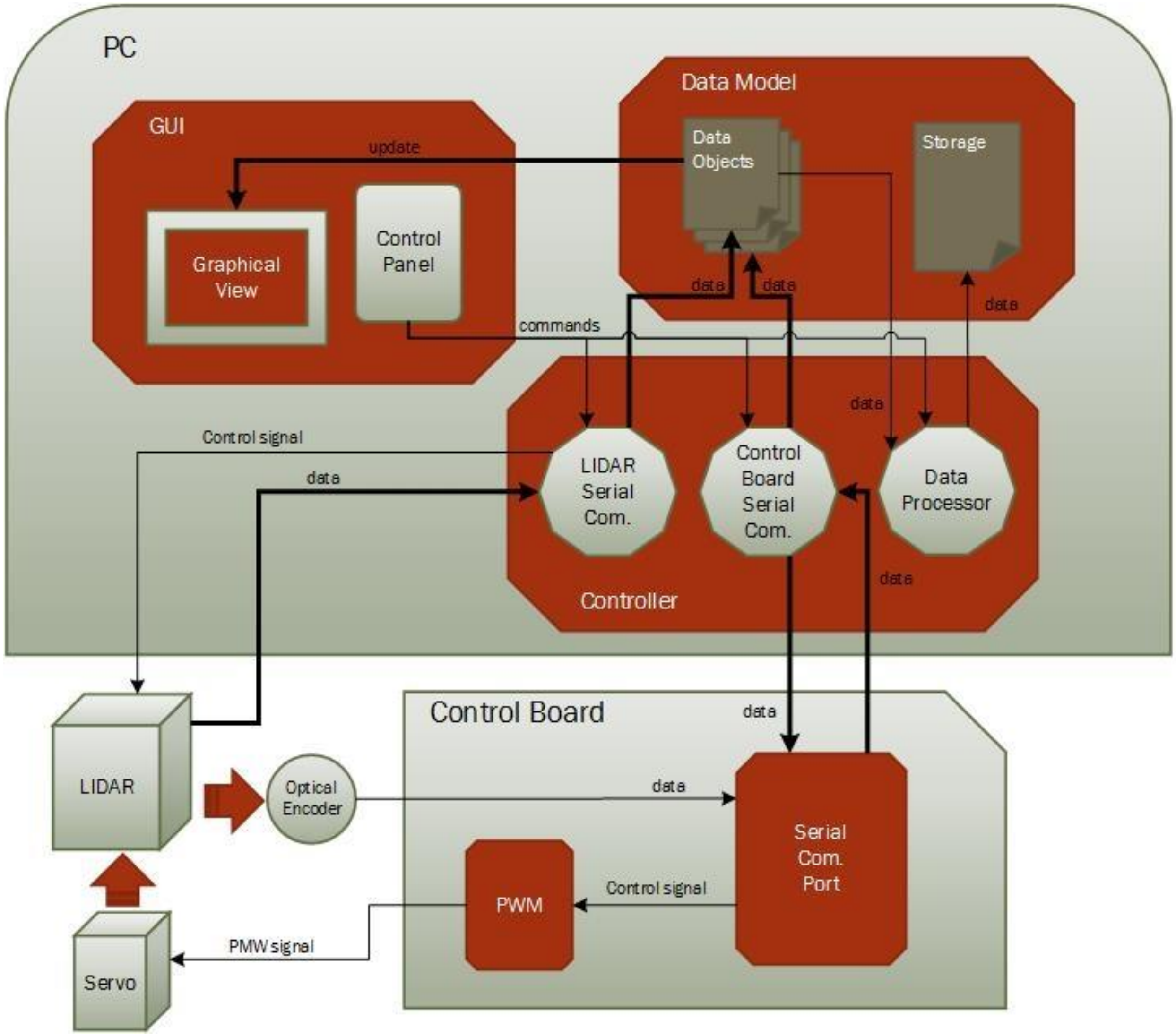
# Concept Sketch




# System Block Diagram



# Software Block Diagram




# System Description

The system will consist of a few subsystems. One of the subsystems will involve a 2D LIDAR that interacts with computer software and collects data for the software. Another system will involve a mechanical platform that can be easily rotated by an industrial servo. The servo will be controlled by a control board that is also been controlled the software. The LIDAR will be mounted on the platform so that when the servo rotates, the LIDAR nods up and down. A third subsystem that involves an optical encoder will be integrated to detect the exact angle positions of the LIDAR. The optical encoder provides feedback to the control board and the control board sends that data to the software.

The computer software will perform the main controls of the system. When the software gets the data from the LIDAR and the control board, it interprets the data into a 3D graphical representation for the user. This 3D representation will be processed and drawn by the CPU, not a GPU. There are two strong reasons for this design choice. First, this expands the number of systems that can run our software. By not needing a GPU, more systems can be used to control and interpret the LIDAR. Second, a GPU simply isn't need. The 3D rendering we will be doing is really just drawing a number of points and coloring each to represent its distance from the LIDAR. This is a simple task and shouldn't require the extra horsepower of a GPU. The end goal will be to integrate this system into another larger system, such as large machinery or the Iowa State Lunabotics robot. These larger systems operate at high power but can be dangerous without sensor that can help detect obstacles, targets, and pedestrians.

# Operating Environment

As a team, we will design and create our project as a standalone product that will meet our functional and nonfunctional requirements. Since the LIDAR sensor uses laser beams to detect distances, it can be operated under conditions with or without sunlight. The LIDAR can be used under 0°C and can be operated outdoors. Eventually, our system may be installed on large machinery that operates outdoors under unfavorable conditions such as rain, wind, dust, and vibrations. To reduce some of the vibrations, we will mount the LIDAR apparatus on rubber grommets.

# User Interface Description

The user can interact with this system by turning the system ON. Our project provides graphical software that interprets data inputs for the user. The user will be able to run or pause the scan, take screenshots while operating, and configure the LIDAR. On the screen, there will be a radar-like bar updating the screen corresponding to where the sensor is currently scanning.

Ideally, the software should signal the user when there is an object detected. The types of things that can be detected include cliffs, ditches, and pedestrians when a collision is about to happen. Such detection software can be accomplished by image processing but would require complicated algorithms. We will incorporate what we can in the scope of this project. Future developers can upgrade this software and increase its image processing power.

# Functional Requirements

1. Scanning
   Each scan must take less than 1 second to complete
   Each scan must start no more than 0.5 seconds after the previous scan completes

2. Mechanical
   Servo setup must provide positional feedback (ie - be closed-loop)
   Servo must withstand 600 oz/in of torque
   Scanning apparatus must scan at least 120 degrees

3. Software
    - Deliver scan results in a human-readable format
    - Scan results should be visible to the user no more than 0.5 seconds after a scan completes
    - Use RS422 to communicate with LIDAR to achieve necessary baud rate

# Non-Functional Requirements

1. Hardware
    - Hardware should connect to PC via USB
    - The LIDAR should be a SICK LMS-291
        - This design decision was chosen because our design should be able to scan in harsh environments. The SICK LMS-291 was used extensively for the DARPA Grand Challenge because of its robust outdoor functionality.
    - Prototype should be tested while mounted on the provided wheeled cart

2. Software
    - User should be able to operate the system with one window

3. Cost
    - Any needed software should be open source or widely available
    - Cost of prototype must be much less than a 3D LIDAR
    - Cost of servo should be less than $50

# Market/Literature Survey

The market for a 3D LIDAR is a niche market at best, which is partially responsible for the continued high prices seen in the market. 3D LIDARs are really only used for research at this point, so the demand isn't there to lower the price yet. The typical response, then, is to create one's own 3D LIDAR by tilting or rotating a standard 2D LIDAR along the second axis to generate the 3D pointcloud of data.

There are several cases where this has successfully been done, and at least one company that commercially produces a 3D LIDAR using a spinning or tilting 2D LIDAR. MIT has used such device on their ROAMS robot, a robot which autonomously navigates their campus making 3D maps (http://www.technologyreview.com/news/416331/making-3d-maps-on-the-move/?a=f). Michael Bosse and Robert Zlot used a spinning 2D LIDAR to collect 3D pointclouds in their research for developing a method to eliminate error from 3D scans taken from a moving scanner (http://ubuntuone.com/0aaEvPEHt89dBFlv9B1quk). Hobbyists on a budget are also applying this technique with cheaper 2D LIDARs to create 3D pointclouds (https://sites.google.com/site/mechatronicsguy/turquoisebot/laser-nodder). 3DLS currently sells several different models of spinning or tilting 3D LIDARs based off the LMS 200 series. They also sell kits for converting an existing LMS 200 series LIDAR into a 3D LIDAR (http://www.3d-scanner.net/index.html). We can see from all the work others have done in this area that this is a reasonable and feasible solution to the problem of expensive 3D LIDARs.

Research has also shown that there are tools available for making the collection of the 3D pointcloud easier. ROS, the Robot Operating System (http://wiki.ros.org/), provides native 3D pointcloud collection. It even provides a framework specifically for collecting this pointcloud from a tilting 2D LIDAR. This OS is becoming the industry standard for these kinds of projects, and has a great support community, including tutorials for building 3D pointclouds with a tilting 2D LIDAR.

Our background research has shown that creating a 3D LIDAR from a tilting 2D LIDAR is a feasible and reasonable solution to the cost problem of a native 3D LIDAR. Since several different groups of varying skill levels have created this kind of device, it should be feasible for us to do the same. ROS's native support for this operation will also be very helpful.

# Deliverables

The expected deliverables for this project includes a GUI providing basic control of the servo and LIDAR as well as displaying the scan data in human readable format (ie - pictorially). This should be developed with open-source software and operate on a readily available Linux distribution.

The scanning apparatus will be able to securely hold a 2D LIDAR scanner and precisely position it. The servo should connect to a servo controller or a generic microcontroller, which will be connected to the PC. The LIDAR will communicate with either the microcontroller or the PC directly.

The testing and demonstration of this project will at minimum be the scanning apparatus resting on a table with the PC by its side displaying the output. This will be running in real-time, allowing visitors to interact with the scan and view the output. If time permits, we will mount the apparatus on an RC mobile base and communicate with a PC wirelessly.

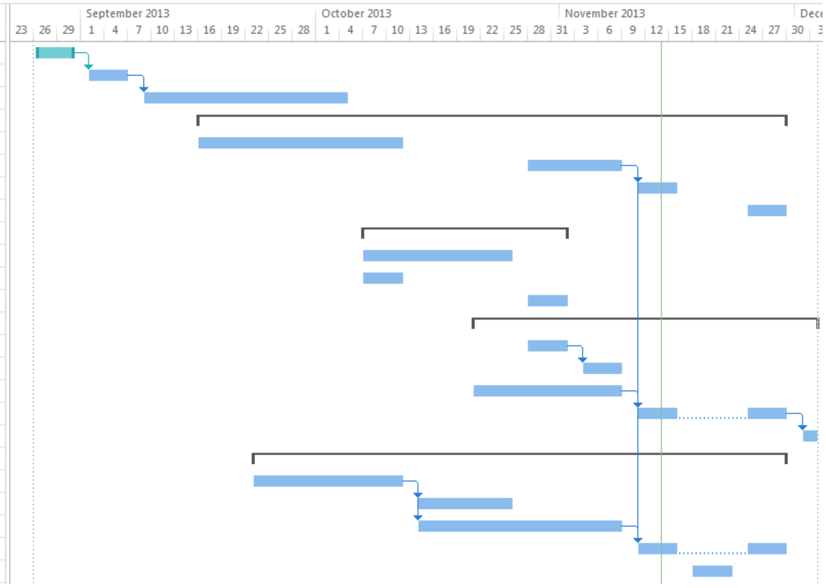
# Work Plan

## Work Breakdown Structure

We first elected Nicolas Cabeen as the group leader and Todd Wegter as the group communicator. The group leader delegates tasks and helps make crucial decisions when the group is in disagreement. The communicator arranges meeting times with everyone, coordinates communications between the group and the advisors, and submits the weekly report. From here the project can easily be broken down into three categories: mechanical, electrical, and computer. Todd Wegter is taking lead on the mechanical portion of the project. This includes designing the apparatus that moves the LIDAR, fabricating any components required, and connecting any required equipment to the base. Eric VanDenover is in charge of the electrical component of the design which consists of any circuit design or fabrication required and connecting the LIDAR, servo motor, and controller to the computer. The computer portion has two parts. Nicolas Cabeen is working on the communication between the computer, servo, and LIDAR. Xiang "Peter" Wang has taken charge of interpreting the data from the LIDAR and servo to make a graphical representation of it.

## 491 Project Schedule

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| Project Selection | 4.5 days | Mon 8/26/13 | Fri 8/30/13 |
| Meet Advisor | 5 days | Mon 9/2/13 | Fri 9/6/13 |
| Lab Resource Allocation | 20 days | Mon 9/9/13 | Fri 10/4/13 |
| **Documentation** | **55 days** | **Mon 9/16/13** | **Fri 11/29/13** |
| Project Plan | 20 days | Mon 9/16/13 | Fri 10/11/13 |
| Design Documentation | 10 days | Mon 10/28/13 | Fri 11/8/13 |
| Project Plan v2 | 5 days | Mon 11/11/13 | Fri 11/15/13 |
| Final Documentation | 5 days | Mon 11/25/13 | Fri 11/29/13 |
| **Mechanical** | **20 days** | **Mon 10/7/13** | **Fri 11/1/13** |
| Servo Research | 15 days | Mon 10/7/13 | Fri 10/25/13 |
| Software Setup | 5 days | Mon 10/7/13 | Fri 10/11/13 |
| Apparatus Sketchup | 5 days | Mon 10/28/13 | Fri 11/1/13 |
| **Electrical** | **32 days** | **Mon 10/21/13** | **Tue 12/3/13** |
| Compile Tech Specs | 5 days | Mon 10/28/13 | Fri 11/1/13 |
| Tech Spec Review | 5 days | Mon 11/4/13 | Fri 11/8/13 |
| Design PCB | 15 days | Mon 10/21/13 | Fri 11/8/13 |
| Breadboard PCB | 10 days | Mon 11/11/13 | Fri 11/29/13 |
| Order PCB | 2 days | Mon 12/2/13 | Tue 12/3/13 |
| **Software** | **50 days** | **Mon 9/23/13** | **Fri 11/29/13** |
| Software Research | 15 days | Mon 9/23/13 | Fri 10/11/13 |
| Computer Setup | 10 days | Mon 10/14/13 | Fri 10/25/13 |
| ROS Tutorials | 20 days | Mon 10/14/13 | Fri 11/8/13 |
| Proof of Concept in Lab | 10 days | Mon 11/11/13 | Fri 11/29/13 |
| BREAK | 5 days | Mon 11/18/13 | Fri 11/22/13 |




## Resource Requirements

We will require the following resources for our development:

- 2D LIDAR
- Industrial-grade servo
- Servo controller/microcontroller
- RS422 to USB converter box
- Linux PC
- Multi-output Power Supply (0-24V)
- Aluminum for apparatus construction
- Bearings for apparatus construction

## Risks

| Risks | Mitigations |
|---|---|
| We are not able to find a servo in our budget | Use surplus parts or find sponsorship to find a servo |
| The LIDAR and servo cannot collect data quickly enough to be usable | We can compress data and drop resolution as needed to meet speed requirements |
| The inherent risk of shock injury from working with electrical equipment | Follow lab policies and procedures<br>Wear a ground strap |
| The provided equipment is very expensive and we may not be able to replace it if it breaks | Read and know the technical specifications of the equipment<br>Follow proven procedures<br>Don't work by yourself or when you're tired or impaired |