# A Low-Cost, Reliable, and Portable System to Record Marksmanship Hits and Misses and Present Feedback in Real Time


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## Background & Motivation

Defense Research and Development Canada (DRDC) is in need of a projectile detection sensor system for conducting marksmanship studies. The current system (SIUS LOMAH) is able to collect data within the accuracy requirements of the client. However, there are a few issues with this system. These include a time consuming setup and calibration process, lack of feedback about the calibration offset and operation status of the sensor system, the collected data is not easily exportable for further analysis, and the client-side user interface is lacking in its representation of the collected data and usability.

The focus of the proposed design was the accurate collection of marksmanship data, secure transmission of this data, and clear digital representation of the data for the soldiers and the researchers. Additionally, our team targeted portability, easy installation and calibration. The above mentioned considerations enable easier operation, simplified processing of data, and improved marksmanship.

## Introduction

The project was organized into three systems: the Detection System, Communication System, and User Interface & Data Store. The Detection System is powered by a series of micro-controllers that return real-time data to the local web server. The web server stores the collected data in local Data Store (Database). The web server serves the User Interface via a web browser to various user devices.

## Detection System Constraints

- Must be able to determine the impact location of a 5.56x20mm projectile travelling at least 900 m/s fired from a C-7 rifle
- Accurate within 10mm after initial calibration
- Detect projectiles within a 30cmx30cm region and the
- design will be scalable to 2mx2m
- Support the use of different paper target models
- Be able to run on battery power for at least 8 hours on a single charge
- Be functional in indoor test conditions

## User Interface System Constraints

- Client application must work on the current latest versions of Chrome (53.0.2785.143), Firefox (49.0.1), Safari (10.0) for desktop and tablet devices.
- Authentication system must provide two sets of privileges:
- Administrator & general user (i.e. soldiers)
- Be able to hide/show metric panels
- Able to export data (along with the calibration offset) in CSV format
- Display sensor status

## Detection System

The Laser System is to use an array of light sensors and LEDs, and record the light level seen by the sensors. On the target frame, a linear array of sensors will be placed on the top and left portion of the frame, and a laser mounted on the bottom and right parts of the frame. When the bullet passes the through the target, it will result in a dimmed light level for a particular sensor for both the top sensor array and the left sensor array. This results in a precise vertical and horizontal coordinates of the point the bullet passed through the target.

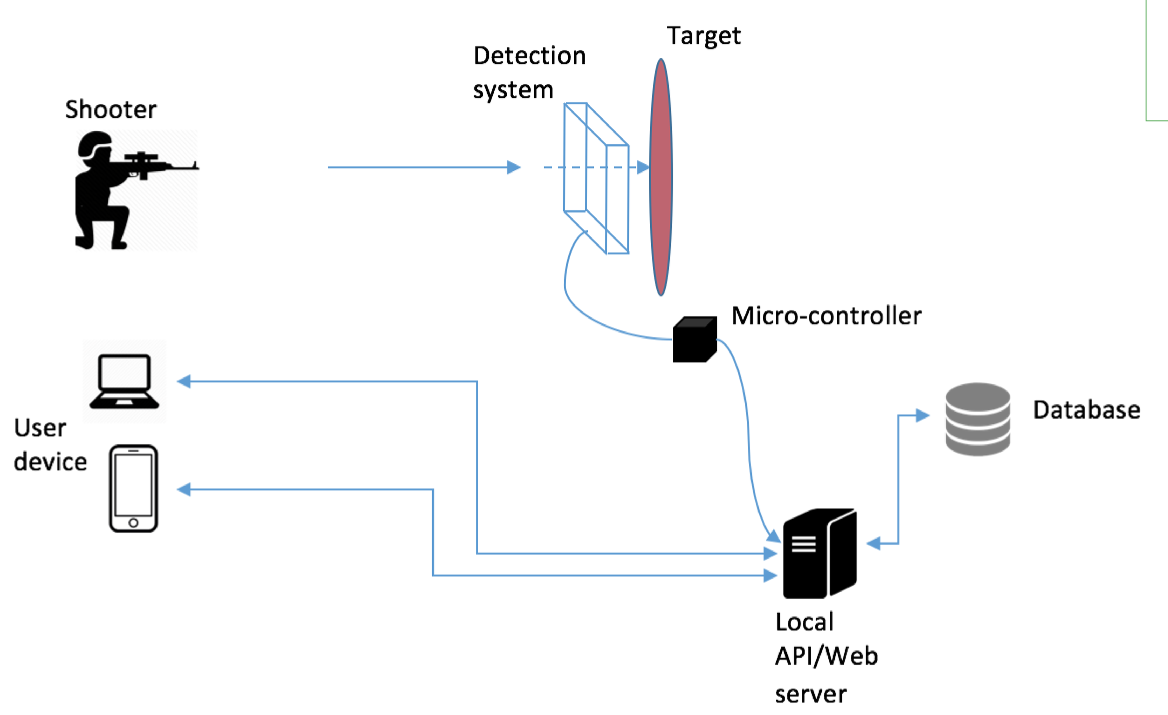


**Figure 1.** Overview of the design and sub systems.

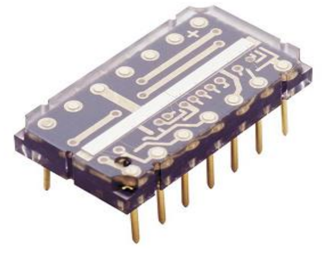

**Figure 2.** TSL1402 sensor used in the design.[1]

## Sensors & Circuits

The solution developed by the team was to use a set of precision linear sensor arrays developed by AMS, designated as TSL1402R. The key advantage to using these devices is that majority of signal processing circuitry required to analyze the sensor output is internal to the chip. In addition, each 2cm device contains 256 sensors, allowing for very precise measurement of which light sensor experienced a reduction in light. [1]

There are four distinct circuits within the detection system The first is the sensor circuit, which outputs a digital signal if the voltage of the sensor is below a certain threshold during a read operation. The second is the pixel recording circuit, which stores which pixels were indicated by the sensor circuit to be below the voltage threshold. The third circuit is the control circuit, which is where the microcontroller reads the data from the pixel recording circuit. It also outputs system wide signals such as the clock. The fourth circuit is the power circuit, which supplies power with constant regulation to other circuits.

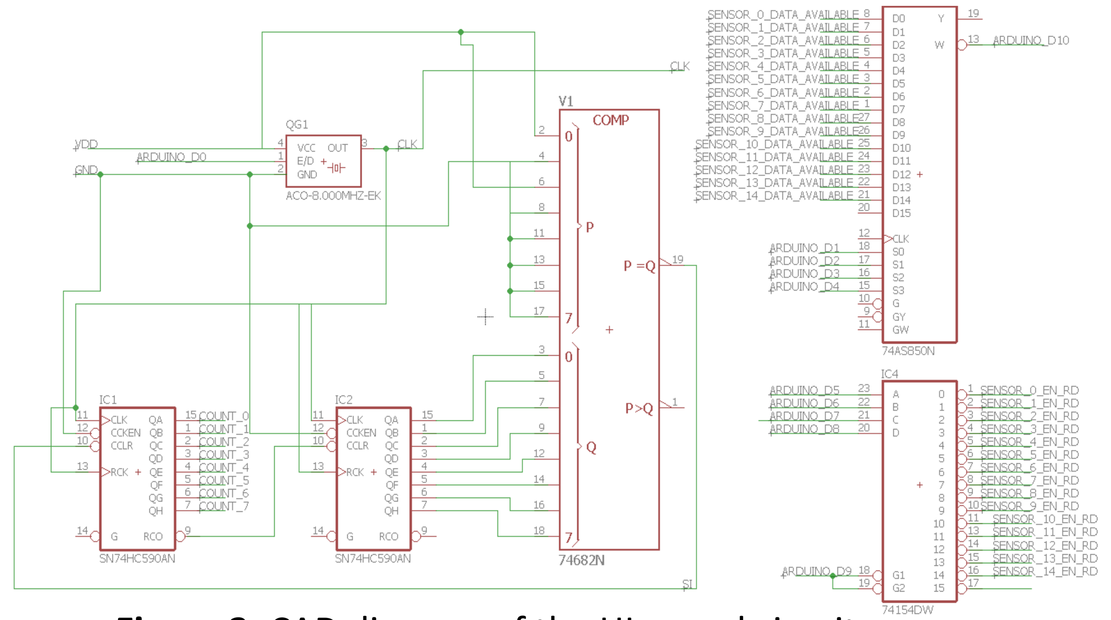

**Figure 3.** CAD diagram of the HI-speed circuits.

## API & Data Store

The marksmanship sensor data is stored in a MYSQL database. The data in the database is exposed through a basic API server. The API server uses standard HTTP for communication with producers, consumers of the data. The API server and the database are deployed inside a container to ensure ease of setup across systems.

The API exposes the following endpoints that can be used to access relevant data:

/users (the users in the system)
/targets (the target configurations, e.g. size)
/shots (the shots that have been captured,
e.g. coordinate_x, coordinate_y, user, timestamp)

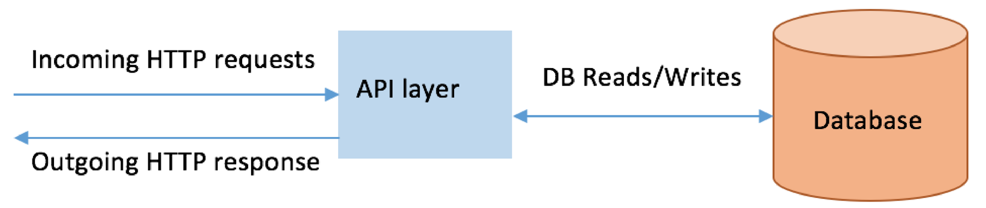


**Figure 4.** UML interaction between the API Layer and DB.

## Calibration

External factors such as wind may lead to the detection frame being tilted. In order to account for such factors, the design makes use of a gyroscope to determine the offset in the angle of the frame at any given point of time. The gyroscope device continuously provides raw data in the form of yaw, pitch, and roll. These angles are against an initial reference angle that is determined at the time of system boot.

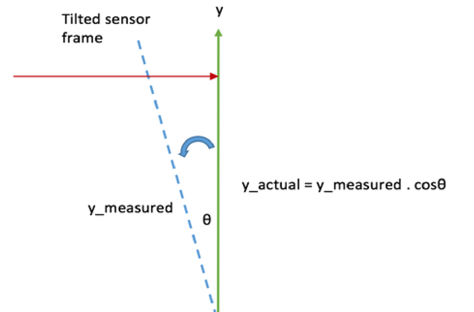


**Figure 5.** Example of the offset calculation.

## Integration and Sensor Data processing

An Arduino microcontroller is responsible for reading the data from the sensors and writing them into a serial FIFO buffer. Each sensor writes 256 pixels of data into the FIFO buffer. A Raspberry Pi micro-controller does a complete read of the FIFO buffer along an axis at a time, for example from S1-S4. It then processes the data to determine where the coordinates that have deviated from the saturated light intensity. After doing so, it makes an HTTP request to the API server to store the processed data.

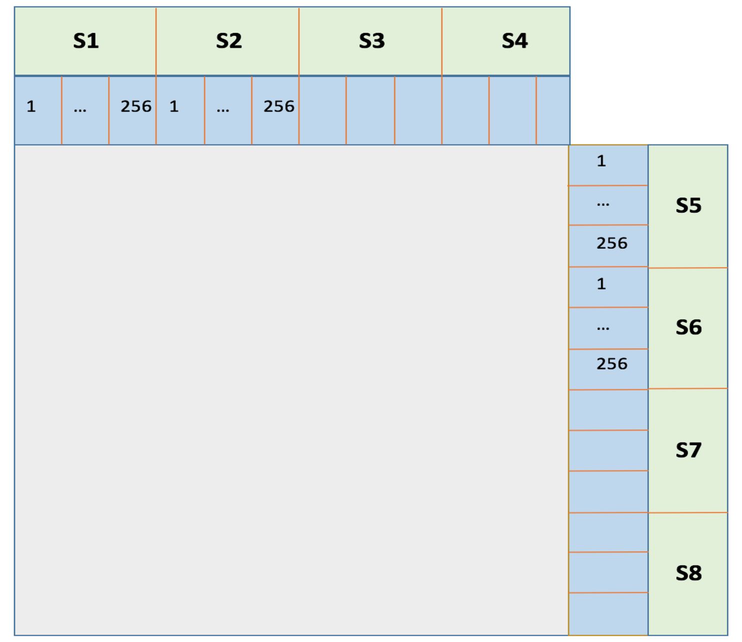


**Figure 6.** Diagram showing sensors side-by-side with pixels.

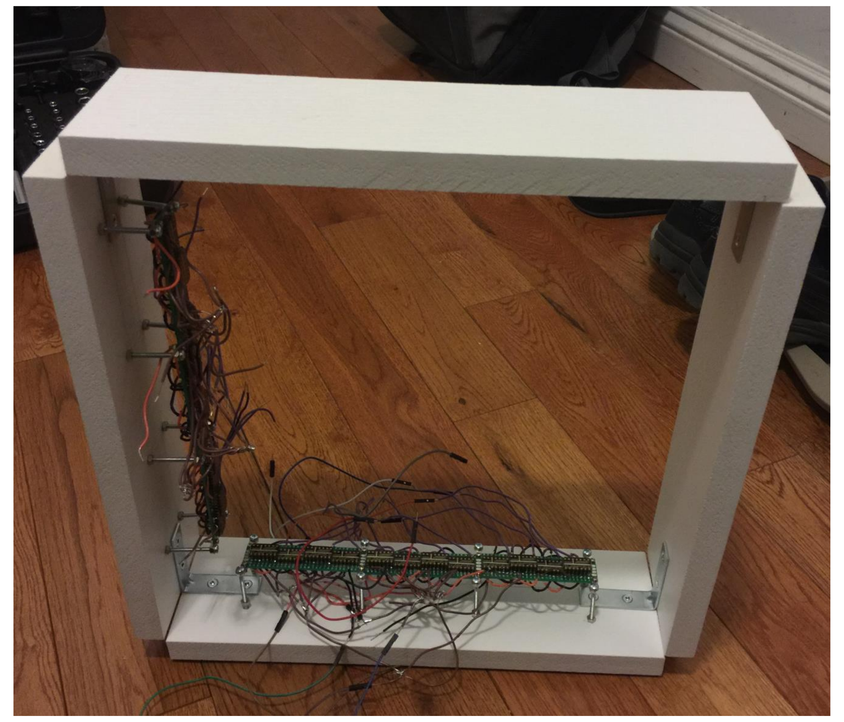

**Figure 7.** Completed frame built using PVC trim.

## Frame Design

The frame was built using four cuts of 32 cm PVC trim. It is engineered to resist expansion and contraction and has a hard surface that protects against dents and weather damage. PVC trim was the ideal material to use for the prototype as it is easy to cut and to drill like wood but without the downsides such as weathering. For the production version of our design, aluminum will be used alongside steel for shielding.

## Testing

A 5.56mm bullet travelling at 940 m/s will cross the target frame in 21 microseconds. The design team used a point laser and point laser detector and modulated the point laser at 500kHz to determine the ability of a detector diode to respond to changing amplitude of light. A 21 us crossing is more closely approximated by a 50kHz signal, but 500kHz was used as extra margin and for experimental purposes.

Additional testing and characterization was performed on the TSL1402R. A LED light source 30 cm from the sensors and a 5mm object was placed in between the LED and sensor at equal distance. The purpose was to determine the output for typical operating conditions.

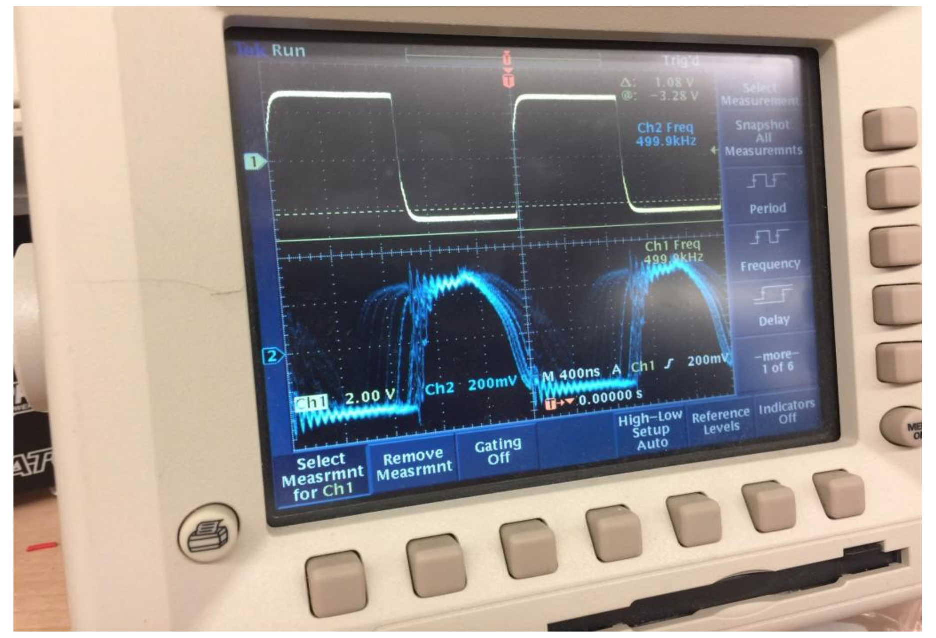

**Figure 8.** Oscilloscope showing an 8 MHz signal and the response received from the sensor (Analog).

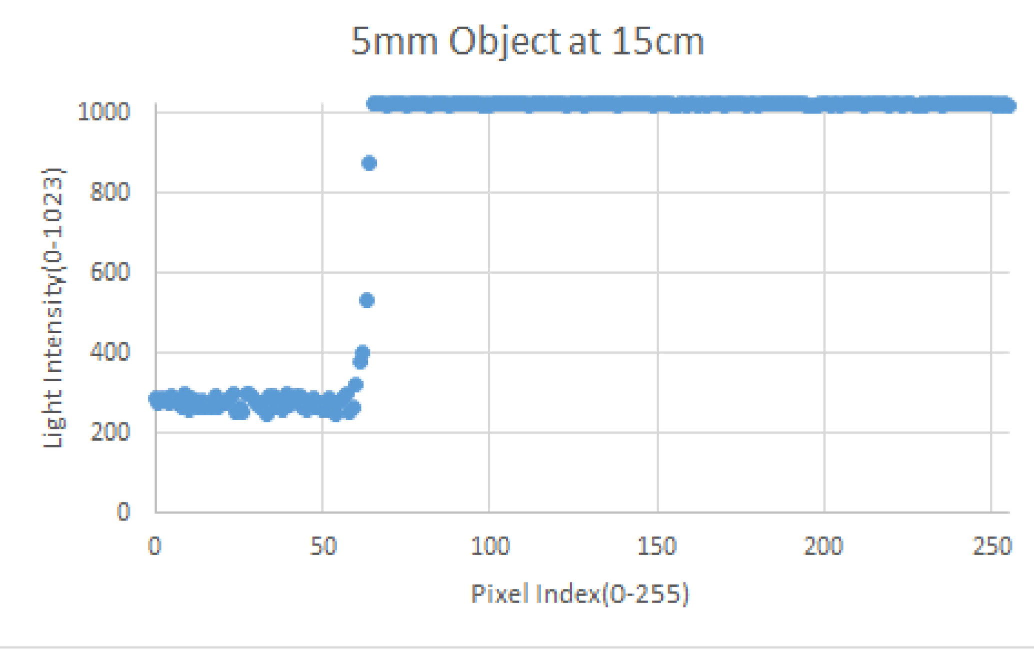


**Figure 9.** Output from the sensor with a 5 mm object blocking the light source.

## User Interface

The user would be interacting with the web application on an ASUS Transformer Pad. Other features include:

- Displays the detected shot in real time.
- A CSV file containing the all the shot data is available to download.
- Users can set theme color to their liking.

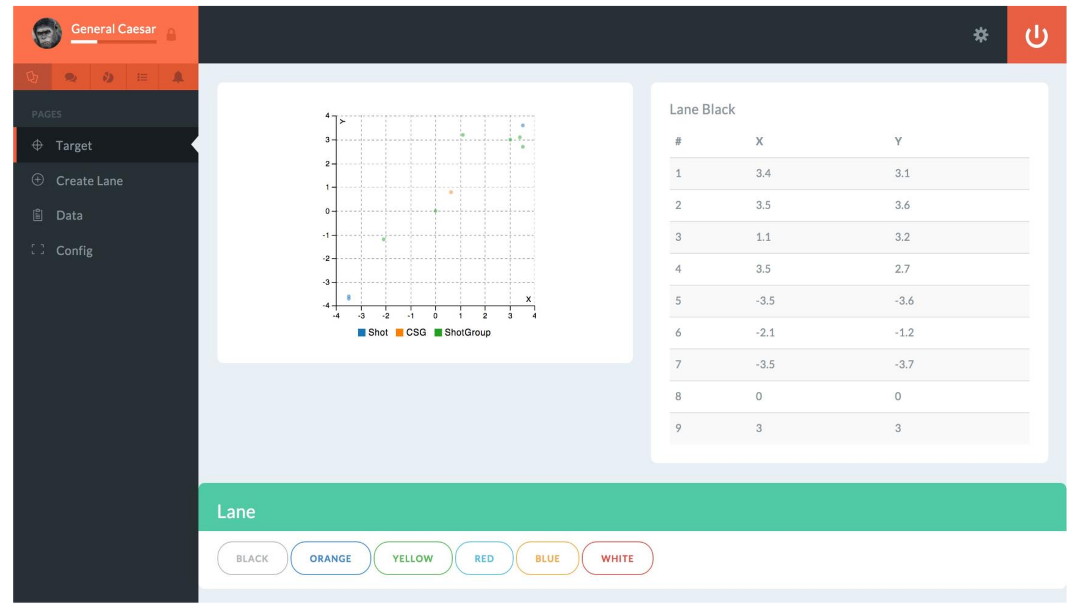

**Figure 10.** The targeting dashboard showing shots taken by a marksmen.

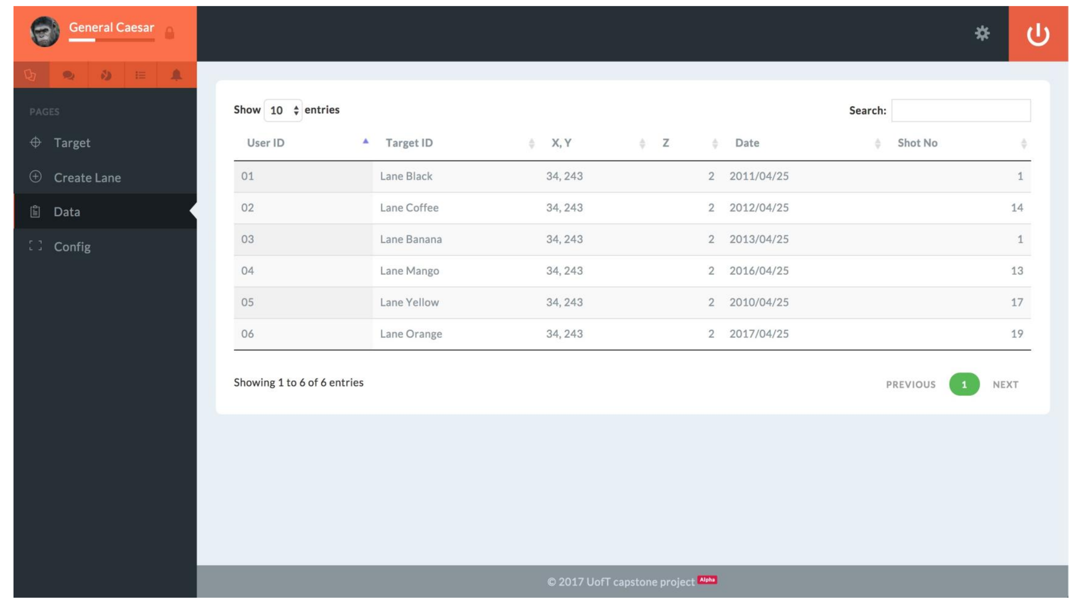

**Figure 11.** The admin dashboard allows researchers to output the data.

## Results & Next Steps

On March 31, our team will be heading to a indoor shooting range to test our design. An expert marksman, provided by DRDC, will be using a C7 rifle with standard NATO rounds to test our design. The results will be incorporated into our final design document.

## References


[1] "Arduino playground - TSL1402R," 2017. [Online]. Available: http://playground.arduino.cc/Main/TSL1402R. Accessed: Feb. 1, 2017.