Abstract
Spectre Battlezone is a twist on traditional laser tag without using lasers. Each player is provided a rifle configured for gameplay. The rifle is equipped with a digital display showing a real-time map and current player statistics along with location of teammates, opponents, and in-game upgrades.

The goal of the project was to design a system comprised of smaller embedded systems. The design was to include embedded linux development tools, modern communication protocols, and to make laser-tag more like an Arena Shooter!

Methods & Materials

**Protocols Used**
- SPI, I2C, MQTT, TCP, Socket.IO
- UWB (decawave custom logic)
- Linux System Calls (ioctl, fcntl)

**Programming Languages**
- C, Javascript, CSS, HTML

**Laser Rifles (Tags)**
- Raspberry Pi 3
- Decawave DWM1000 (UWB)
- LSM9DS1 (IMU)
- Battery Pack
- 3.5" HDMI Display

**Locationing Anchors**
- Raspberry Pi Zero
- Decawave DWM1000 (UWB)

**Gameserver**
- PC with Arch Linux

Magnetometer Offset
The raw magnetometer data was sampled and forced to be centered at the origin. This provided a global heading reference for gameplay.

The rifles were configured to send raw status at the end of one full location refresh over a WiFi connection to the gameserver. The gameserver would then perform a global update and push game data back to the rifles through a javascript browser.

UWB 2-Way Ranging
Ranging protocols consist of handshakes between modules, with 2-way implying that both modules have the chance to initiate a handshake. The distance is extracted by timestamping the Rx and Tx actions, performing a Time of Flight algorithm and correcting clock skew between modules.

On average, the raw status of one player could be polled in 231ms. This brings a maximum system refresh time to 1.44 Hz with a prior goal of 4Hz.

Results
The end system was synchronous and produced input usable for a scaled down version of laser-tag. Although the system would not be adequate for large scale applications, it successfully demonstrates the enhanced features described. Several lessons learned include:

- Test driven development
- Optimization through refactoring
  - Optimal performance requires out of the box thinking
  - Early system-level debugging
- Timing analysis and system synchronization

Gameplay GUI
User interfaces showing the location and status of all players involved in a current game.

System Timing Diagram
UWB dictates that only one connection can be had at any given time. As such, system timing was required to be very precise and finely tuned. Each module in the system was synchronized using MQTT signals.

Server GUI
Player GUI

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