# Falling Object Sensing Helmet

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## Introduction

Construction workers are exposed to significant risks from falling objects which can cause severe injuries despite the use of traditional hard hats. Currently, workers primarily rely on verbal warnings to avoid falling objects, a method that can be unreliable. The Falling Object Sensing Helmet has been developed to enhance safety on construction sites. The helmet, integrates a Doppler radar sensor, ESP32 microcontroller, power distribution board and a dual alert system to alert its user of potential falling objects. The primary objective is to provide a real-time warning system for construction workers, reducing the risk of head injuries caused by falling objects on hard hats.

## Objectives

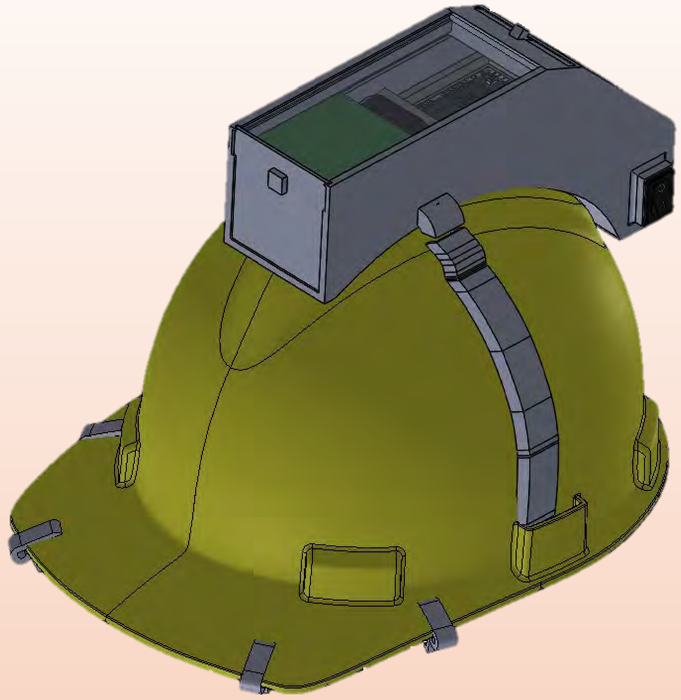
- Develop a reliable sensor-based detection system for objects with a radar cross-section(RCS) greater than 0.5$m^2$
- Minimize response time for user alerts.
- Optimize helmet design for usability and comfort
- Validate system performance through testing
- Measure sensor detection range and field of vision
- Gather user feedback to assess comfort and ease of use.

## Design Metrics

| Metric | Unit | Value | Results |
|---|---|---|---|
| Acceleration error | Percent difference | <10% | >10.8 |
| Detection range (RCS=0.5 m²) | m | >10 | >11 |
| Detection field of vision | Degrees | ≥ ±30 | ±35 |
| Detection time (RCS=0.5 m²) | ms | <440 | 782 |
| Amount of alert modules | Count | >3 | 5 |
| Helmet weight | kg | <1 | 0.798 |
| Helmet center of gravity | mm | >-46.5 <56 | -46.5 |
| Comfortability | Average score out of 10 | >7 | 8.75 |

## Acknowledgements

We thank Michael Kay for securing us a testing location. We also thank Evan Oliver for assisting in helmet construction and testing.



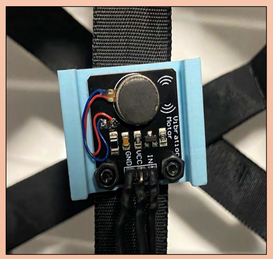
## Helmet Design

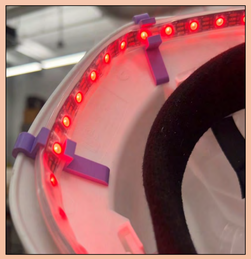
### Sensing

A Doppler radar sensor detects falling objects by measuring velocity, determining if an object moves at a dangerous speed. The system is programmed in Rust using an asynchronous framework for safety guarantees and performance.

### Alerting

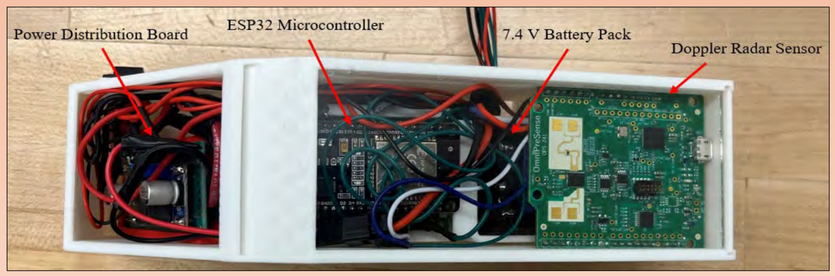
The helmet features LED mounts for visual alerts and haptic feedback modules for tactile alerts, ensuring immediate warnings in any environment.





### Housing

A custom, 3D-printed enclosure securely holds the radar sensor, ESP32, power distribution board, and wiring while keeping the design compact, lightweight and protected from dust or debris.




## Key Results

Velocity data was recorded of falling objects with various RCS. We found that the helmet detects higher RCS objects more reliably. The minimum RCS we tested that gives an average detection time less than 440 ms was 80 $m^2$.

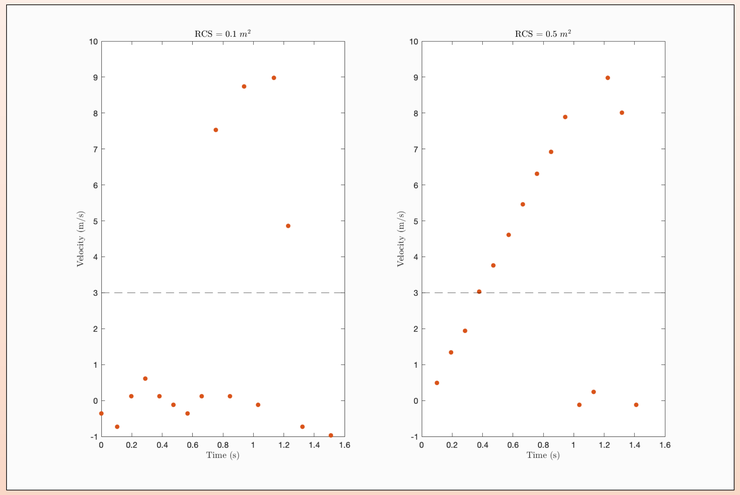



Figure 1: Velocity data from two different radar cross sections (RCS). Dotted line represents the velocity threshold for alert.

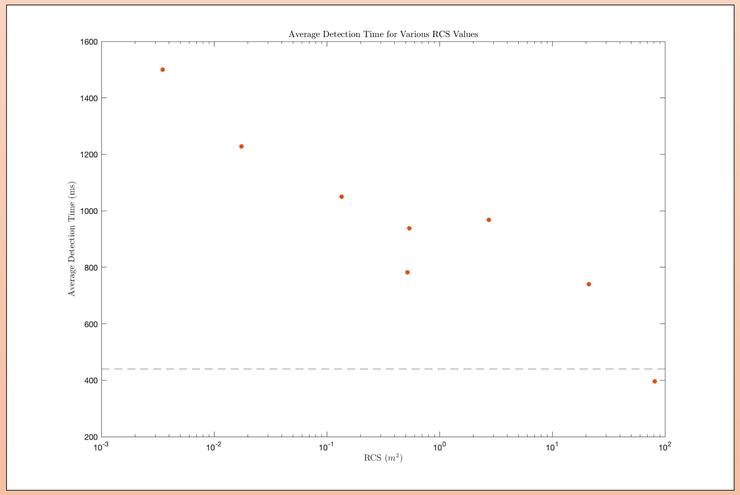



Figure 2: Average detection time of falling objects of various RCS values plotted on a log scale. Dotted line at 440ms represents our benchmark for system reaction time. Data was captured with a 60Hz iPhone camera.

## Conclusion

The Falling Object Helmet successfully detects objects with high RCS within an angle of tilt of ±30°. Based on user feedback, the helmet is acceptable to wear for long periods. Future steps for this project would be investing in a more advanced sensor to detect objects with lower RCS more reliably. Additionally, including a longer lasting battery would allow the system to stay reliable for longer and reduce weight and size of the housing mount.