

Four-Wheel Steering Integration and Sensor Platform for Woodpecker LSEV

Final Report

Joshua Lizee

Sarah McAllister

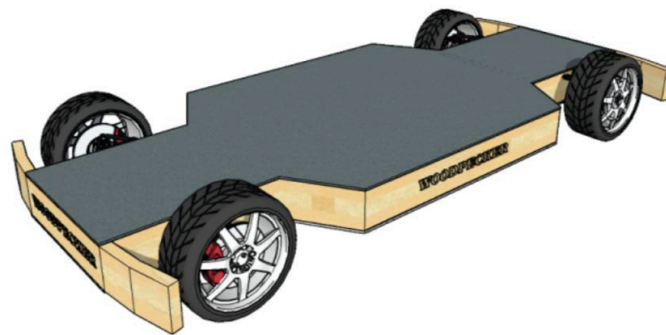
MJ Santos

Torstein Helland

Alexander Hickey

Kaleo Humber

2026



Project Sponsor: Michael O'Halloran

Faculty Advisor: Dr. Joseph Piacenza III

Instructor: Dr. Elliott Clement



DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such, they are not responsible for the accuracy of results or conclusions.



ABSTRACT

This project focuses on the continued development of the Woodpecker Low Speed Electric Vehicle (LSEV), an open-source modular skateboard platform [1] intended for controlled warehouse and industrial environments [2]. Building on the work of previous capstone teams, this project focuses on steering integration and sensor platform readiness to improve maneuverability, controllability, and future expandability of the vehicle platform. The design effort centers on modifying and adapting an existing steering kit to fit the current vehicle architecture, including the implementation of a rack-and-pinion steering [3] setup with chassis reinforcement. In parallel, mounting provisions and interface considerations are being developed to support future sensor integration and experimental testing.

A major goal of the project is to create a functional and drivable prototype that integrates the steering system, chassis, and sensor-ready mounting features into one cohesive platform. Key design priorities include reliable steering performance, stable low-speed vehicle control, manufacturability, and ease of assembly. Major engineering challenges include alignment between steering and chassis components, packaging limitations, and compatibility issues between off-the-shelf kit parts and custom-designed components.



ACKNOWLEDGEMENTS

We would like to acknowledge our instructor, Dr. Elliott Clement, and advisor, Dr. Joseph Piacenza III, for their guidance and support through our project. We'd also like to appreciate our sponsor, Michael O'Halloran, for his resources, insight, and patience as well as iLabs shop staff for the assistance. Finally, we acknowledge our team members for their collaboration.



TABLE OF CONTENTS

Contents

DISCLAIMER	1
ABSTRACT	2
ACKNOWLEDGEMENTS	3
TABLE OF CONTENTS	4
1 BACKGROUND	2
1.1 Introduction	2
1.2 Project Scope	2
2 DESIGN PROCESS	3
3 DESIGN PROPOSAL – First Term	4
4 Design Solution	6
4.1 Description of Solution	6
4.2 Project Results	6
5 LOOKING FORWARD	8
6 CONCLUSIONS	9
7 REFERENCES	10

1 BACKGROUND

1.1 Introduction

The Woodpecker Low Speed Electric Vehicle (LSEV) is an open-source, modular skateboard-style platform intended for controlled warehouse and industrial environments. This capstone project builds on previous team efforts by improving steering integration and developing a sensor-ready platform that can support future testing and research. The work centers on adapting an existing steering kit to the current vehicle architecture, integrating the steering system into the donated chassis, and resolving packaging and fitment issues that affect drivability and manufacturability. The chassis for this project was donated by Michael O'Halloran, the team's primary sponsor, making the project directly relevant to the sponsor's interest in advancing the Woodpecker platform into a more functional and usable research vehicle.

The main objectives of this project are to produce a functional and drivable prototype, establish a reliable front steering baseline, and create a clear mechanical path for future upgrades such as rear steering and additional sensor integration. To meet these goals, the team is addressing critical design challenges, including steering system alignment, interference between the steering input shaft and the platform, interference between the control arm and tire rim, and compatibility between off-the-shelf kit components and custom vehicle features. By focusing on steering performance, stable low-speed control, and assembly-friendly integration, the project aims to deliver a platform that is not only operable in its current form but also practical for future development.

This project is important because low-speed electric vehicle platforms are only valuable for research and demonstration when their mechanical systems are predictable, repeatable, and well integrated. In current engineering practice, there is growing interest in modular electric vehicle platforms for industrial mobility, warehouse transport, and experimental autonomous systems, but those applications depend on a reliable mechanical foundation before higher-level sensing and control can be meaningfully added. For the sponsor, Oregon State University, and future capstone teams, the completed project provides a stronger platform for continued development, reduces rework through cleaner subsystem integration, and improves the long-term usefulness of the Woodpecker LSEV as a testbed for future research and design iterations.

1.2 Project Scope

The scope of this project includes the mechanical integration, packaging, and validation of the steering system, along with the development of a sensor-ready vehicle platform. From the team's perspective, the project is centered on delivering a controllable and testable low-speed vehicle configuration that can serve as a baseline for future development. This includes modifying and mounting the steering rack to fit the current chassis, addressing interference issues such as steering input shaft interference with the platform and control arm interference with the tire rim, evaluating packaging changes such as wheel spacing and rack mounting angle, and integrating the steering, chassis, and mounting features into a manufacturable assembly.

The project scope also includes planning and incorporating provisions for future sensor mounting so the platform can support later experimental and research use. Decision tools such as the House of Quality, Pugh screening, and a risk-based phased design strategy are used to guide tradeoff decisions and align the design with customer requirements and engineering constraints.

Items outside the scope of this project include braking system development, autonomous control development, and full autonomous vehicle implementation, since those responsibilities are assigned to the other team. Depending on the success of this term, final validation of a complete four-wheel steering system is also not guaranteed. Instead, the emphasis is on solving the current mechanical integration problems and delivering a steering platform that is functional, manufacturable, and ready for future subsystem development.



2 DESIGN PROCESS

The current process has been very structured due to the previous work completed for this project. The Capstone team that began last Fall had done extensive work on the overall vehicle design and primarily needed our team to incorporate the suspension and steering assemblies onto the new wooden chassis to bring the vehicle to an operation status. This allowed us to jump directly into the steering integration work with very little need for early-stage ideation or broad conceptual design generation. As a result, many of the foundational system decisions, such as geometry and dimensions, mounting locations, power systems, and the control systems, had already been established before our team became involved. Rather than starting from a blank slate, we were able to begin with an existing framework, defined boundaries, and clear performance expectations.

Specifically, the previous team had already completed the design and fabrication of the wooden chassis and made substantial progress toward implementing the vehicle's power and control systems. Our responsibility, therefore, has been to analyze this existing structure and determine how to properly integrate the suspension and four-wheel steering assemblies. Our design process has involved reviewing prior CAD models, taking precise physical measurements of the chassis, identifying hard mounting constraints, and evaluating load paths to ensure that steering and suspension forces are properly transferred through the wooden frame. We have also considered manufacturability and serviceability, ensuring that components can be assembled, adjusted, and maintained without compromising structural integrity.



3 DESIGN PROPOSAL – First Term

The comprehensive proposal for the Woodpecker LSEV centers on transforming the partially developed open-source platform into a fully functional, maneuverable, safe, and adaptable vehicle capable of serving multiple low-speed transportation applications. The core objective of our team’s contribution is to integrate a four-wheel steering system, and suspension assemblies onto the recently fabricated wooden chassis, while ensuring compatibility with the existing power and control systems and enabling future expansion. This solution builds directly upon the prior Capstone team’s structural and electrical groundwork and advances the platform from a static prototype into an operational vehicle.

At the heart of the design is the mechanical integration of a four-wheel steering system. The wooden “skateboard-style” chassis presents both opportunities and constraints. Its lightweight construction reduces overall vehicle mass, improving efficiency and lowering power requirements, but it also requires careful attention to loading, mounting reinforcement, and fastener design to ensure structural durability. The four-wheel steering configuration significantly reduces the turning radius compared to traditional front-wheel-only steering, which is particularly advantageous for low-speed environments such as farms, warehouses, campuses, and industrial facilities. Improved maneuverability directly enhances usability across all anticipated applications.

Complementing the steering system is the integration of suspension that maintains tire contact with the ground while accommodating uneven terrain and dynamic loads. The suspension design was reused from the previous iteration of the Woodpecker LSEV, and focuses on simplicity and reliability. Given the low-speed nature of the LSEV, the suspension does not require high-performance damping characteristics typical of highway-speed vehicles, but it must provide sufficient compliance to protect both the frame and mounted subsystems from vibration and impact loads. Proper alignment between steering linkages and suspension geometry has been carefully considered to minimize bump steer and ensure predictable handling. By addressing steering and suspension simultaneously, the solution ensures cohesive vehicle dynamics rather than treating these systems independently.

The braking system forms another critical component of the comprehensive solution. A four-wheel disc braking configuration provides consistent stopping power and redundancy, improving safety compared to two-wheel braking setups. Hydraulic actuation is used for primary braking due to its reliability, controllability, and widespread industry acceptance. Brake line routing is designed to minimize interference with steering components and suspension travel while protecting lines from debris and mechanical damage. Additionally, a secondary or emergency braking system, likely pneumatic or mechanically actuated, is incorporated to provide fail-safe capability. This layered safety approach ensures that the vehicle meets functional expectations for controlled operation in shared spaces where pedestrians and obstacles may be present.

Beyond mechanical functionality, the solution is designed to remain compatible with the broader vision of autonomous capability. Although a separate team is leading sensor integration and autonomy development, our mechanical layouts account for sensor placement, cable routing, and structural mounting points. Steering response characteristics and braking controllability are considered in light of potential autonomous control inputs, ensuring that mechanical systems can respond accurately and predictably to electronic commands. This forward-looking integration prevents costly redesigns and preserves the modular philosophy of the Woodpecker platform.



Modularity is a defining principle of the overall solution. Because the Woodpecker LSEV is not designed for a single fixed use case, the mechanical architecture emphasizes adaptability. Mounting points will be designed to accommodate different cargo modules, seating configurations, or specialized attachments without requiring structural redesign. For agricultural use, the platform could support produce bins or towing attachments. For industrial environments, it may carry tool racks or assembly fixtures. For mobility-focused applications, it could be configured with accessible seating and safety restraints. By maintaining standardized mounting points and accessible mechanical layouts, the vehicle can evolve alongside future Capstone teams and community contributors.

Assembly and maintainability are also central to this design. Components have been selected to be available as off-the-shelf parts. Assembly procedures are planned to ensure fasteners, brake bleeding ports, and adjustment mechanisms are accessible. We also avoided overly complex geometries or specialized components that would increase cost or cause delays. Since the project operates under academic time constraints, practical feasibility is prioritized alongside performance.

Risk mitigation is embedded throughout this design. By utilizing previously sourced steering components, the team reduces procurement risk and lead times. Conservative design margins are applied where uncertainty exists in load estimation. Potential failure modes, such as steering linkage loosening, or hydraulic leakage, are considered during design review. Where appropriate, redundancies or inspection points are incorporated to improve long-term reliability.



4 Design Solution

The objective of this project was to integrate and validate the steering, suspension, braking, and electrical systems of the Woodpecker Low-Speed Electric Vehicle (LSEV) while ensuring compliance with relevant engineering standards and safety requirements. During assembly and initial testing during this term, several structural and geometrical challenges were identified, particularly involving steering rack mounting and vehicle platform integration. To address these issues, the team implemented design modifications, conducted risk assessments, and incorporated applicable automotive and electrical safety standards into the vehicle design.

4.1 Description of Solution

Initial testing revealed significant floor deformation around the steering rack mounting points when steering loads were applied. To improve structural rigidity, perforated steel square tubing was installed beneath the plywood floor and attached to the frame walls. The steering rack mounting hardware was redesigned so that loads were transferred through the steel reinforcement rather than directly into the plywood. This solution increased stiffness while preserving the existing steering rack configuration and minimizing additional fabrication.

A second design modification was required after a larger lithium battery was added, which, along with other steering components, created interference between the vehicle platform and these components. To provide sufficient clearance, the platform was elevated using 2×2 wooden supports attached to the existing cover and frame structure. The elevated platform maintains compatibility with the vehicle geometry and allows future teams to implement additional accessibility features, such as a hinged or fold-out cover for easier access to internal components.

The final design was developed to satisfy both engineering specifications and customer requirements for a safe, functional, and reliable low-speed electric vehicle. Structural reinforcement of the steering rack mounting system improved chassis rigidity and steering performance, supporting the reliability and durability requirements of the project. The integration of a larger lithium battery, Battery Management System (BMS), and improved electrical routing aligns with FMVSS 305a, NEC Article 625, and SAE J2929 requirements by reducing electrical shock, fire, and battery safety risks. Compliance with FMVSS 500 was considered throughout the design process by maintaining the vehicle within the intended low-speed vehicle classification and preparing the system for future performance validation. Additionally, the reinforced platform and steering structure help address customer requirements for safe operation, occupant protection, and long-term usability. By incorporating risk mitigation measures such as emergency braking capability, structural reinforcement, and battery protection systems, the design improves overall safety while maintaining accessibility for future upgrades and maintenance.

4.2 Project Results

The implemented modifications successfully improved the structural robustness of the vehicle and reduced steering rack-induced floor deformation. Initial unloaded testing demonstrated reliable operation of the steering, braking, and throttle systems, with consistent and predictable responses. The reinforcement strategy increased confidence in the durability of the steering system and addressed a key structural weakness identified during testing.

Risk analysis identified braking, suspension, steering, and frame failures as the most critical safety



concerns. Mitigation actions reduced the likelihood of these failures through improved hardware selection, reinforcement, inspection procedures, and safety systems. While the vehicle has not yet undergone full testing under its own weight, the project established a solid foundation for future validation efforts. Remaining opportunities include loaded performance testing, platform accessibility improvements, and continued refinement of the electrical and structural systems. Overall, the project achieved its primary objectives of integrating key vehicle subsystems, improving safety and reliability, and advancing the Woodpecker LSEV toward operational readiness.



5 LOOKING FORWARD

This project creates a solid foundation for future Capstone teams to integrate full autonomous capabilities in navigation and control, including the eventual implementation of a complete sensor suite and automated braking system. Although the vehicle will not be fully autonomous at this stage, the design intentionally supports a transition toward autonomy, accounting for current hardware selections to ensure future compatibility. The modular platform also allows various platforms to be swapped depending on the application, enabling use cases such as agricultural support, campus transportation, light cargo delivery, and movement around factories or warehouses. This flexibility of the skateboard chassis ensures the vehicle can continue to evolve both in terms of autonomy and functionality, adapting to changing needs and autonomous capabilities [4].



6 CONCLUSIONS

The implementation of the steering system, development of a modular platform, as well as the implementation of autonomous sensors transforms the Woodpecker LSEV into a maneuverable and adaptable mobility and cargo solution. By improving steering geometry and integrating a flexible cargo/passenger platform, the vehicle can easily be used for campus and cargo transportation applications [5]. The selected designs balance the needs of performance, manufacturability, cost, and expandability. The improvements will improve turning performance, drivability, and application flexibility while maintaining compatibility with future implementation of fully autonomous systems. This proposal reflects a structured design process while keeping in mind customer requirements and offers a clear justification for concept selection. Overall, the project is technically feasible within the available resources and delivers meaningful engineering value toward offering campus-scale autonomous mobility and cargo transportation.



7 REFERENCES

- [1] *E-Mobility Engineering*, "Skateboard platforms," Sep. 2021. [Online]. Available: <https://www.emobility-engineering.com/ev-skateboard-platforms/>.
- [2] R. Gailums, "Woodpecker | Open source electric vehicle platform," *Woodpecker*, 2020. [Online]. Available: <https://woodpeck.org/>.
- [3] "Rack And Pinion Systems Explained," *Engineers Guidebook*. [Online]. Available: <https://engineersguidebook.com/rack-and-pinion-systems-explained/>.
- [4] "Canoo shows off performance and versatility of its skateboard platform," *TaaS News*, 2020. [Online]. Available: https://taas.news/article/112165/Canoo_shows_off_performance_and_versatility_of_its_skateboard_platform.
- [5] J. McIntosh, "How It Works: Electric Vehicle Skateboard Chassis," *Driving.ca*, May 2021. [Online]. Available: <https://driving.ca/column/how-it-works/how-it-works-electric-vehicle-skateboard-chassis>.