

Design Proposal

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Team D605

Four Wheel Steering Integration and Sensor Platform for Woodpecker LSEV

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1. Introduction

The Woodpecker low speed electric vehicle (LSEV) is an open source, modular skateboard platform built around a wooden chassis with in wheel motors and a drive by wire architecture intended for controlled environments such as campuses, factories, and farms [1]. To support Oregon State University's autonomous LSEV initiative, the platform must provide predictable steering behavior, repeatable stopping performance, and well defined mechanical and electrical interface points for rapid experimentation.

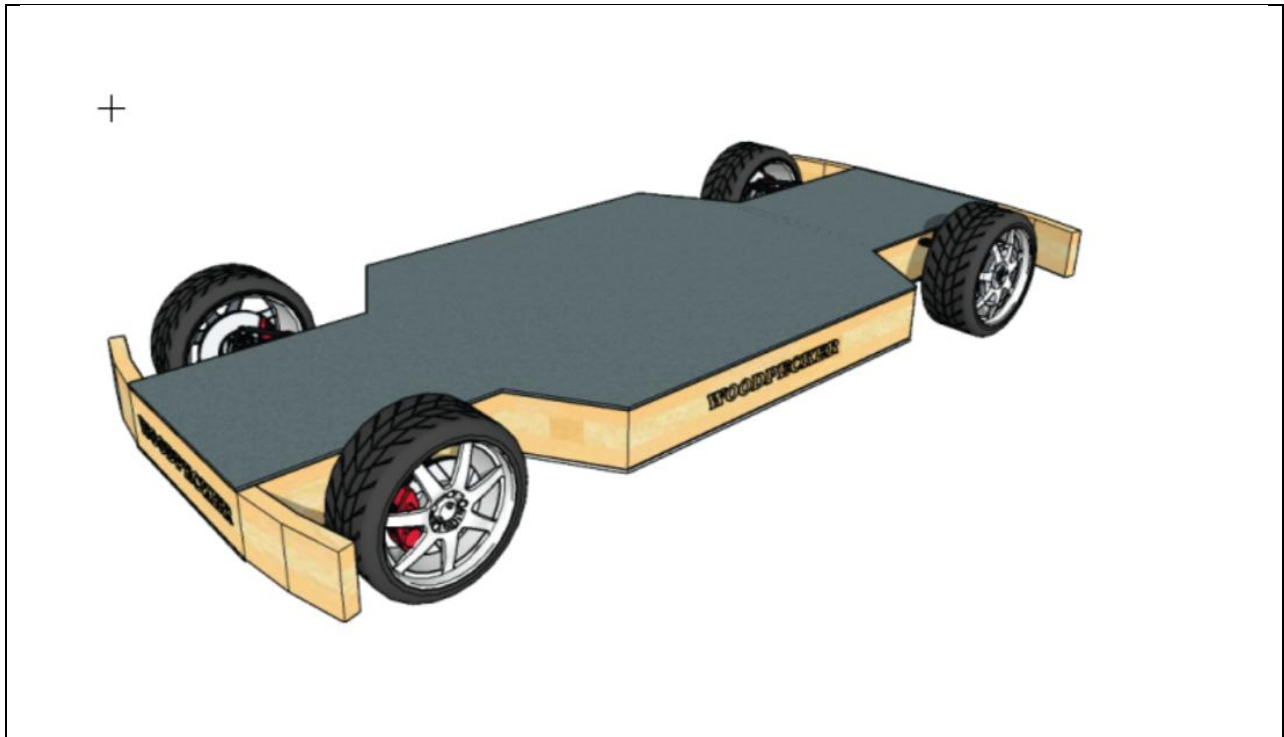


Figure 1. Illustration of the Woodpecker LSEV base platform.

2. Project Scope and Context

Team D605 will integrate an existing Pilot Labs four wheel steering (4WS) kit into the Woodpecker chassis and establish a mechanically robust, sensor ready mounting interface for early autonomous hardware. The steering work includes designing and fabricating mounting plates, brackets, and linkage interfaces for steering actuators, tie rods, joints, and end stops, followed by alignment and performance validation testing.

The project will explicitly avoid scope creep into full autonomy software development. Perception, mapping, planning, and closed loop autonomy control will be owned by future teams and partner groups. In particular, cameras and LiDAR used for line following or perception will be integrated and validated by the parallel autonomous capstone group. Electrical and software deliverables in this phase are limited to defining interfaces and basic bring up support, such as documenting connector pinouts, routing clearances, and sensor mounting datums.

A donated chassis body has been provided by Michael, enabling early hands on integration and testing. Current efforts focus on organizing the chassis, restoring a drivable baseline, and resolving packaging obstacles prior to permanent fabrication. A dedicated power group is responsible for vehicle power system refurbishment and distribution; Team D605 will coordinate mounting space, cable routing clearances, and safety interfaces needed to integrate steering and sensors.

2.1 Stakeholders

Pilot Labs and the Woodpecker open source community provide the reference architecture, documentation, and hardware ecosystem for the platform [1]. Oregon State University's autonomous LSEV initiative and future capstone teams depend on stable steering and sensor interfaces to accelerate autonomy research. Faculty advisors evaluate technical rigor, safety practices, and documentation quality, while the sponsor mentor guides requirements and approves integration decisions. End users in controlled environments benefit from reduced maneuvering space, improved low speed handling, and safer operation [1].

3. Requirements and Success Metrics

Project success will be measured using engineering specifications derived from customer requirements. The primary steering performance target is a 30 ft turning diameter for a vehicle with an approximately 2600 mm wheelbase, with an allowable variation of plus or minus 1.5 ft. This target aligns with maneuvering constraints expected in campus corridors, shop aisles, and farm paths, where U turns and tight cornering dominate low speed operation [1].

Safety requirements include an emergency stop method that removes motor drive commands, plus an independent braking approach with a maximum stopping distance limit over the 0 to 25 mph operating range. A practical upper bound is 2 ft per mph of initial speed, which corresponds to 50 ft (15.2 m) from 25 mph (11.2 m/s). Additional requirements include remote controllability for basic maneuvers, secure sensor mounting without impairing field of view, and basic sensor validation focused on power up, data sanity checks, and repeatability rather than full calibration or perception performance.

Customer Requirement	Engineering Specification	Target / Tolerance
Improved steering radius	Turning diameter at full lock	30 ft diameter \pm 1.5 ft
Emergency stop capability	Emergency stop button disables motor commands	Yes / No
Independent braking capability	Maximum stopping distance from 0-25 mph	\leq 2 ft per mph (\leq 15.2 m from 25 mph)
Remote controllability	Stop, start, left turn, right turn from remote	Yes / No
Low speed vehicle	Maximum speed limit	\leq 25 mph (\leq 11.2 m/s)

Steering tracking	Commanded steering angle accuracy	Within ± 5 degrees
Sensor ready platform	Mounting provisions for LiDAR, cameras, proximity sensors	Secure mount, no major occlusion (pass/fail)
Sensor validation baseline	Repeatability and accuracy vs reference	$\leq 5\%$ error for selected sensors

4. Design Process

The design process for this project follows a simulation to test workflow to reduce rework and ensure that fabrication effort is spent on configurations that are likely to meet requirements. The workflow begins with baseline measurements of the existing chassis and suspension mounting points, followed by a kinematic steering model to relate wheel angles, wheelbase, and track width to turning diameter. Candidate mounting architectures for the 4WS kit are then generated and screened using criteria focused on stiffness, adjustability, manufacturability, serviceability, and load distribution into the wooden frame.

After concept selection, detailed CAD models and drawings will define bracket geometry, hole patterns, and assembly interfaces. Fabricated components will be installed with alignment features that support repeatable toe settings and steering end stops. Testing will then validate turning diameter, steering travel, angle tracking, and interference at full lock. If results deviate from predictions, the simulation model will be updated using measured limits and compliance effects to inform iteration.

4.1 Steering Geometry Modeling Approach

A planar kinematic model will estimate turning diameter as a function of front and rear wheel steer angles, wheelbase, and track width. For low speed maneuvers, tire slip angles are assumed small, so the instantaneous center of rotation can be computed from wheel heading lines. The model will support both counter phase rear steering (rear wheels steer opposite the front) to minimize turning diameter and in phase steering to evaluate potential tracking behavior at moderate speed [2].

The model will be implemented in Python to enable rapid parameter sweeps and sensitivity studies. Key outputs include predicted turning diameter, required actuator travel for a given steering angle, and sensitivity of turning diameter to toe errors and linkage tolerance. These outputs will guide placement of mounting plates and selection of adjustable features such as slotted holes or threaded tie rod ends.

4.2 Sensor Mounting Interface Concepts

Sensor mounting provisions will be designed to be modular and repeatable. A rail based interface on the flat deck area supports repositioning without re drilling the wood and enables future teams to mount different sensors with minimal fabrication. The initial mechanical design will provide a

forward facing mounting mast or crossbar for LiDAR and cameras, plus attachment points for short range proximity sensors at the vehicle perimeter. Cameras and LiDAR algorithms for line following and autonomy demonstrations will be handled by the autonomous capstone group; this team's deliverable is the mechanical mounting and interface readiness.

Sensor validation in this phase is limited to mechanical and basic functional checks: verifying that mounts remain rigid under vibration, confirming that wiring and service access are practical, and demonstrating that each sensor produces stable data streams within expected error bounds in static tests. Full calibration procedures and autonomy performance validation are intentionally deferred. In the following spring term, the team expects to help characterize select sensors such as an IMU module and refine recommended placement on the vehicle based on vibration and data quality.

5. Current Progress

The team is outfitting the wooden Woodpecker frame with suspension and steering assemblies and establishing a drivable baseline configuration. Two near term integration blockers have been identified: obtaining wheel spacers to achieve required track width and clearance, and designing mounting plates and bracketry to securely attach steering components to the wooden chassis while preserving adjustability.



Figure 2. Current suspension and steering assembly integration state (rear corner).

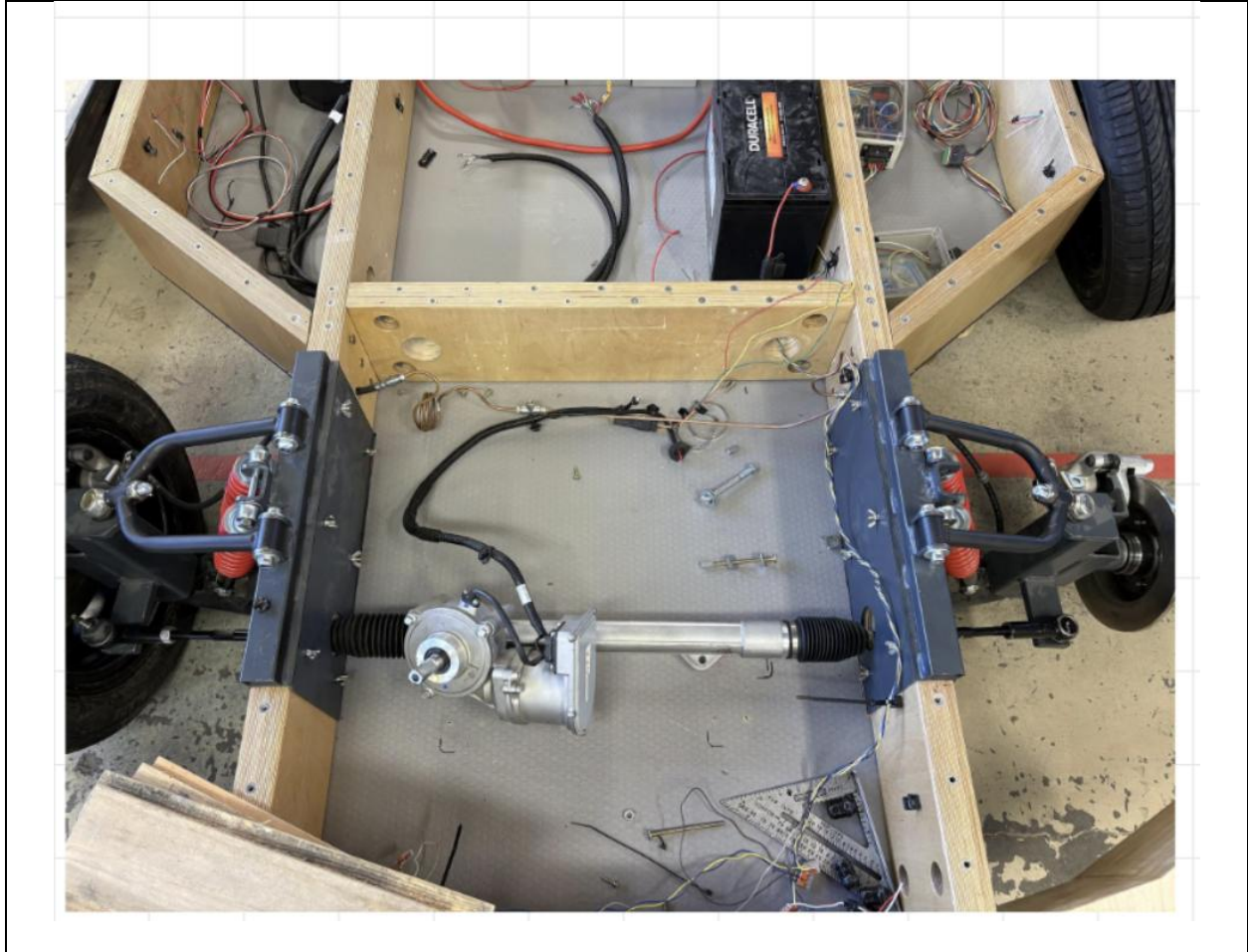


Figure 3. Rear steering rack placement and packaging within the chassis envelope.

6. Proposed Design Solution

The proposed design combines a through bolted sandwich mounting approach with localized steel cross members to create stiff, repeatable datums for steering hardware while distributing loads into the wooden chassis. Steering mounts will use paired plates on both sides of the wood with backing washers or plates sized to limit bearing stress. Where alignment sensitivity is high, cross members will provide a rigid reference plane for rack or actuator mounting and reduce differential deflection between left and right mounts.

Adjustability will be preserved using threaded tie rod ends and accessible jam nuts, plus configurable steering end stops to prevent interference at full lock. The design will include defined measurement features such as scribe lines or reference holes to support repeatable toe settings during testing. All fabricated parts will be documented with drawings that specify material, thickness, hole tolerances, and assembly torque requirements.

6.1 Verification and Test Plan

Steering performance will be validated using a turning circle test on a flat surface. The vehicle will be commanded to full lock, and turning diameter will be measured using a marked path and

tape measurement, repeated across multiple trials to quantify repeatability. Steering angle tracking will be evaluated by comparing commanded angles to measured wheel angles using a digital angle gauge or alignment plates, targeting an error within plus or minus 5 degrees.

An inertial measurement unit (IMU) may also be used as a supplemental validation tool during low speed turning tests. Mounted near the vehicle center of gravity on a rigid chassis reference surface, the IMU can record yaw rate and lateral acceleration during steady state turning. When combined with vehicle speed estimates, these measurements can be used to estimate turning radius and curvature, providing a secondary check against the measured turning circle results. Because IMU based turning estimates are affected by sensor drift, mounting quality, and speed measurement uncertainty, they will be used to support and compare against physical measurements rather than replace them.

Interference and travel limits will be checked by cycling suspension through its range while at steering extremes to confirm clearance. A low speed remote drive test will then confirm basic maneuvers, including stop, start, and left and right turns. Load capability tests will apply representative payload and steering loads to verify that mounts do not loosen and that the wooden structure does not exhibit unacceptable deformation. If time permits, the IMU may also be used to characterize vibration levels at candidate sensor mounting locations for future sensor placement decisions.

6.2 Interfaces to Electrical and Software Teams

Mechanical design will define interface locations and constraints for electrical and software teams. This includes cable routing paths, enclosure mounting areas, and reserved volumes for controllers and sensor compute. Emergency stop integration will be supported by mounting provisions for a clearly accessible button and routing for a safety loop that can disable motor commands. If steering angle feedback sensors are present in the 4WS kit, the mechanical team will document sensor mounting datums and connector access to simplify integration.

Camera and LiDAR hardware used for line following and higher level autonomy functions will be handled by the parallel autonomous capstone group working on the same vehicle. Likewise, vehicle power system design and integration will be handled by the separate power group. In the current phase, Team D605's interface responsibility is limited to ensuring that the steering and chassis design preserves usable mounting space, cable routing paths, and mechanically stable attachment points for those groups. In the following spring term, the team may support future integration by helping characterize selected sensors, such as an IMU, and by evaluating candidate mounting locations on the vehicle for rigidity, vibration exposure, and accessibility.

7. Project Plan and Schedule

The plan targets a drivable, remotely controlled vehicle configuration by Spring Term, followed by quantitative steering validation and documentation.

Step	Key Activities	Primary Owner	Outputs
1	Baseline	All / CAD lead	Measurement log,

	measurements, chassis organization, define steering coordinate system		updated CAD datums
2	Kinematic steering model and sensitivity study, initial mount concepts	Simulation	Model code, turning diameter predictions
3	Fabricate prototype plates and spacers, install and align	Manufacturing / Test	Prototype hardware installed
4	Remote drive bring up, set end stops, iterate bracketry as needed	Test / All	Drivable baseline, issue log
5	Quantitative turning circle and angle tracking tests, update model	Test / Simulation	Test data set, updated model
6	Finalize mount design, finalize documentation and report figures	All	Final drawings, integration documentation

8. Risks and Mitigation

The dominant technical risk is misalignment or compliance that increases tire scrub, binding, or prevents meeting the turning diameter target. This will be mitigated through early modeling, rigid mounting datums, and repeatable alignment procedures. A second risk is mechanical interference at full lock or through suspension travel. This will be mitigated through CAD packaging checks and physical lock to lock cycling prior to powered tests.

The wooden chassis introduces risks related to fastener pullout, joint loosening, and long term durability under steering loads. Mitigation includes sandwich mounting plates, torque control, use of locking features, and periodic inspection. Programmatic risks include part lead times and scope creep into autonomy software. Mitigation includes ordering long lead components early and maintaining a clear boundary that autonomy development is out of scope for this phase.

9. Conclusions

This design proposal defines a measurable path to integrate a four wheel steering kit and a sensor ready mounting interface on the Woodpecker LSEV. Steering success will be evaluated against a

30 ft turning diameter target with plus or minus 1.5 ft tolerance and a commanded angle tracking target within plus or minus 5 degrees, while safety is supported through an emergency stop interface and an independent braking approach consistent with low speed operation. The proposed sandwich plate mounting architecture is intended to distribute steering loads into the wooden chassis while enabling repeatable alignment and service access. Project roles are intentionally bounded: cameras and LiDAR for line following and autonomy demonstrations are owned by the parallel autonomous capstone group, and the vehicle power system is owned by a dedicated power group. Team D605 will deliver the mechanical steering integration, a validated 2WS baseline and upgrade path to 4WS, and sensor mounting interfaces with clear documentation; in the spring term, the team expects to support sensor characterization (e.g., IMU vibration and placement) to strengthen autonomy readiness. By following a simulation to test workflow and documenting mechanical and electrical interface points, the project will reduce integration ambiguity and deliver enabling infrastructure for future autonomy teams to build on.

References

- [1] Woodpecker, "Woodpecker: Open source electric vehicle platform," woodpeck.org, accessed Jan. 2026.
- [2] Whitehead, J. C., "Four Wheel Steering: Maneuverability and High Speed Lateral Response," SAE Technical Paper 880642, 1988.
- [3] Ariff, M. H. M., "Optimal Control Strategy for Low Speed and High Speed Four Wheel Active Steering Vehicle," 2015.
- [4] MathWorks, "Kinematic Steering for Ackermann, Rack and Pinion," Vehicle Dynamics Blockset Documentation, accessed Jan. 2026.
- [5] WoodpeckerCar, "Woodpecker_Frame (CAD repository)," GitHub, accessed Jan. 2026.