Design Proposal for ENGR Capstone Design
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Team ENGR-D601

Autonomous Low Speed EV Platform Development (Year 2)

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1 Introduction

Autonomous vehicles are becoming more common as industries look for safer and more efficient ways to move materials and equipment. Low-speed electric vehicles (LSEVs) are especially useful in controlled environments such as university campuses, manufacturing plants, and in agricultural settings because they can transport goods over short distances without the need for constant human input. As automation becomes more accessible, these vehicles will offer a practical way to improve efficiency while maintaining safety and reliability.

This project focuses on developing an autonomous platform for a LSEV at Oregon State University (OSU). This is the second year of the project that builds upon a net-negative carbon emissions Woodpecker skateboard chassis as seen in **Figure 1**, a remote-controlled vehicle platform [1, 2]. This year's effort integrates autonomous navigation, safety systems, and modular functionality to create a vehicle capable of transporting materials between OSU machine shops (iLabs), with potential future use in agricultural applications.

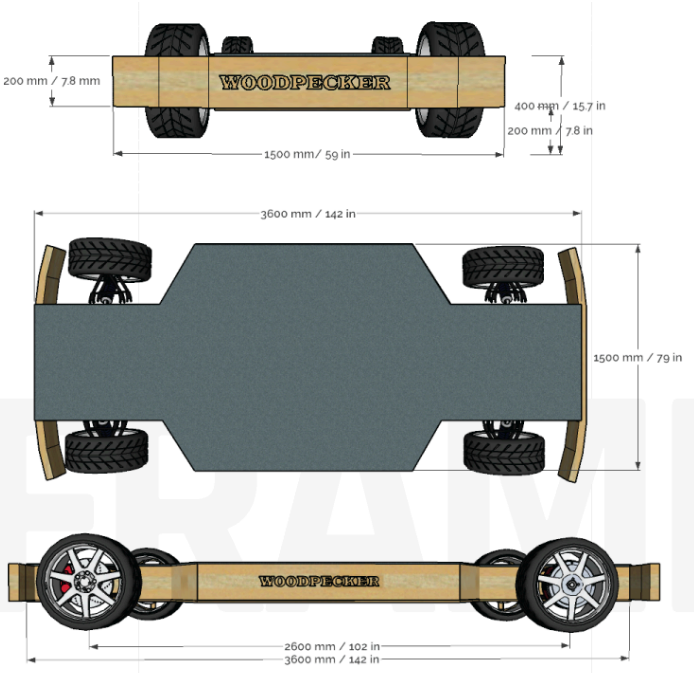


Figure 1: Woodpecker design and dimensions. Adapted from [1].

The project currently involves fourteen students working across multiple subsystems. Two fall-winter capstone students are responsible for returning the vehicle to its original chassis, while the remaining teams focus on major system upgrades. Six students make up the autonomous systems team, which is responsible for navigation, sensing, and safety functionality. Another six students form the four-wheel steering team, which focuses on mechanical articulation and modular attachment capability. This division of responsibilities allows the project to address complex mechanical and control challenges simultaneously while maintaining steady progress across subsystems.

Two primary functional requirements guide this design. The vehicle must reliably follow a predefined route between locations, and it must detect obstacles and automatically stop to prevent collision. These requirements prioritize safe operation where pedestrians may be present while keeping the system robust and practical within the project constraints.

Modularity is another key requirement. The project sponsor, Michael O'Halloran, and mentor, Joseph Piacenza, require the platform to support interchangeable attachments, including a cargo bed for transporting materials and the footprint to attach a cherry-picking robot for agricultural use. Designing universal attachment points and ensuring compatibility across these use cases are essential to maximizing the platform's long-term value.

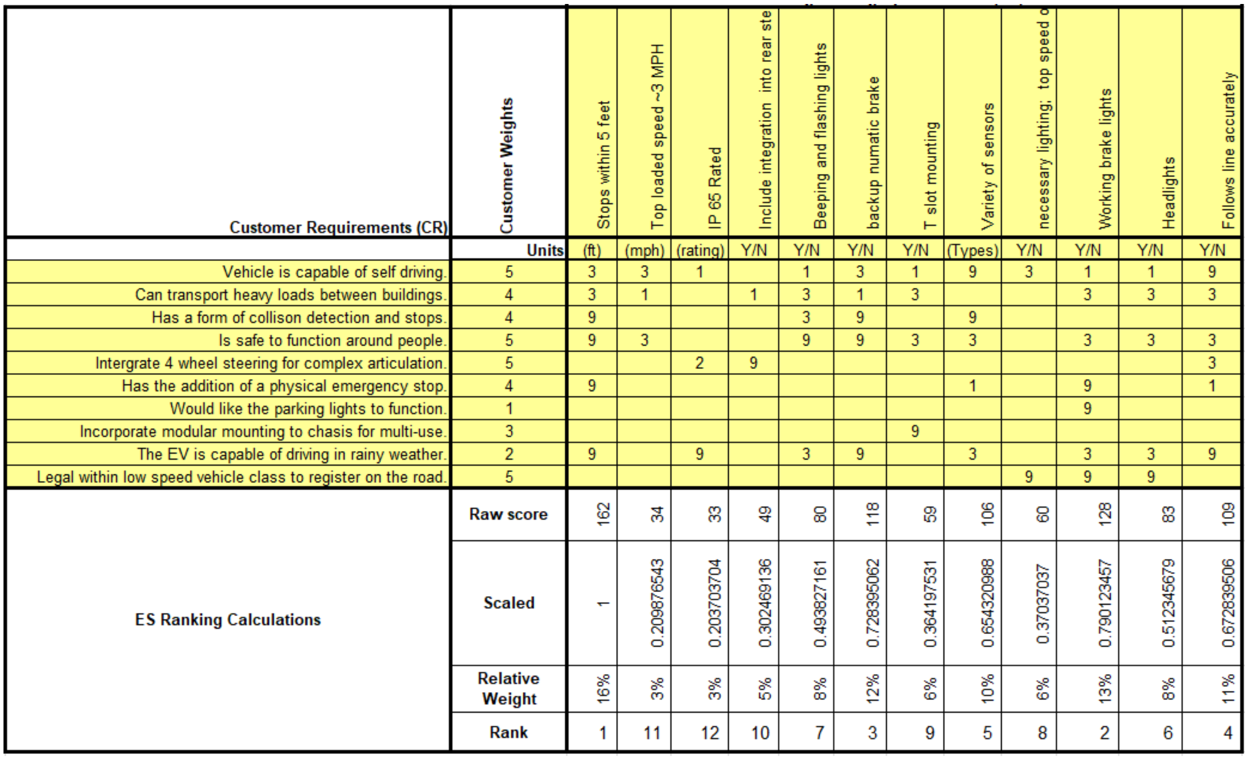
2 Design Process & Alternatives

To ensure the proposed vehicle meets stakeholder needs and project constraints, the team followed a structured design process that prioritized requirements, organized a project timeline, and evaluated multiple solution concepts.

2.1 House of Quality and Requirement Prioritization

The design process began with the development of a House of Quality (HOQ) to translate customer needs into measurable engineering specifications as seen in **Figure 2**. Key customer requirements included autonomous operation, safe and reliable transportation between buildings, modular payload capabilities, and collision avoidance. These requirements were weighted to reflect their relative importance to the project's success.

Engineering specifications were then mapped to these requirements to guide the design decisions. Some examples include safe stopping distance, low-speed operation, water resistance, and line following accuracy. By quantifying relationships between requirements and specifications, the HOQ emphasized safety, reliability, and modularity while ensuring the vehicle remained practical within budget and operational constraints.

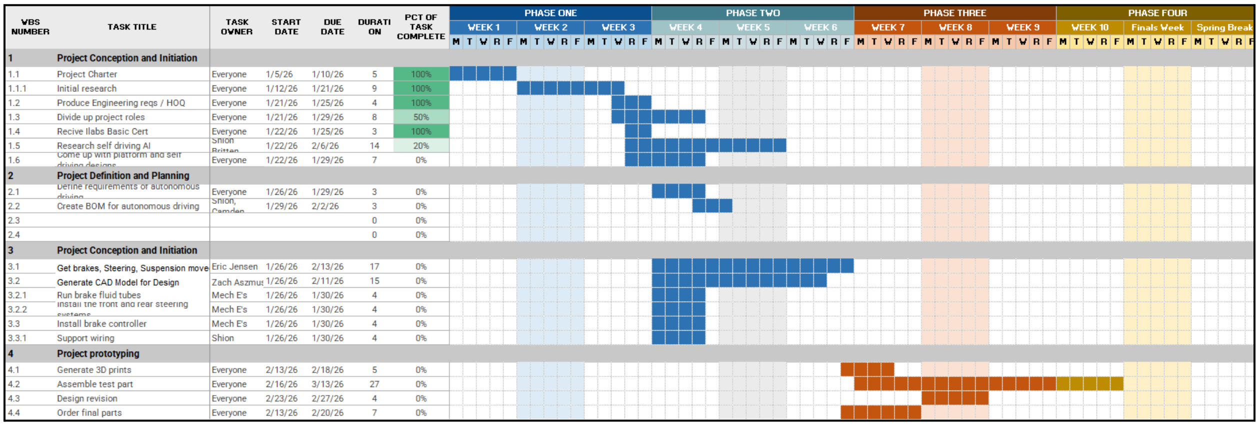


Customer Requirements (CR)	Customer Weights	Stops within 5 feet	Top loaded speed ~3 MPH	IP 65 Rated	Include integration into rear ste	Beeping and flashing lights	backup numatic brake	T slot mounting	Variety of sensors	necessary lighting; top speed o	Working brake lights	Headlights	Follows line accurately
	Units	(ft)	(mph)	(rating)	Y/N	Y/N	Y/N	Y/N	(Types)	Y/N	Y/N	Y/N	Y/N
Vehicle is capable of self driving.	5	3	3	1		1	3	1	9	3	1	1	9
Can transport heavy loads between buildings.	4	3	1		1	3	1	3			3	3	3
Has a form of collison detection and stops.	4	9				3	9		9				
Is safe to function around people.	5	9	3			9	9	3	3		3	3	3
Intergrate 4 wheel steering for complex articulation.	5			2	9								3
Has the addition of a physical emergency stop.	4	9							1		9		1
Would like the parking lights to function.	1										9		
Incorporate modular mounting to chasis for multi-use.	3							9					
The EV is capable of driving in rainy weather.	2	9		9		3	9		3		3	3	9
Legal within low speed vehicle class to register on the road.	5									9	9	9	
ES Ranking Calculations	Raw score	162	34	33	49	80	118	59	106	60	128	83	109
	Scaled	1	0.209876543	0.203703704	0.302469136	0.493827161	0.728395062	0.364197531	0.654320988	0.37037037	0.790123457	0.512345679	0.672839506
	Relative Weight	16%	3%	3%	5%	8%	12%	6%	10%	6%	13%	8%	11%
	Rank	1	11	12	10	7	3	9	5	8	2	6	4

Figure 2: HOQ developed by the autonomous platform team.

2.2 Project Planning and Scheduling

To maintain progress through the term, the team developed a Gantt chart outlining the major tasks, subsystem milestones, and deadlines as seen in **Figure 3**. The schedule coordinated work for the autonomous platform team while adapting to individuals strengths and experience.



VBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Project Conception and Initiation**					
1.1	Project Charter	Everyone	1/5/26	1/10/26	5	100%
1.1.1	Initial research	Everyone	1/12/26	1/21/26	9	100%
1.2	Produce Engineering reqs / HOQ	Everyone	1/21/26	1/25/26	4	100%
1.3	Divide up project roles	Everyone	1/21/26	1/29/26	8	50%
1.4	Recive Ilabs Basic Cert	Everyone	1/22/26	1/25/26	3	100%
1.5	Research self driving AI	Shion Britten	1/22/26	2/6/26	14	20%
1.6	Come up with platform and self driving designs	Everyone	1/22/26	1/29/26	7	0%
2	**Project Definition and Planning**					
2.1	Define requirements of autonomous driving	Everyone	1/26/26	1/29/26	3	0%
2.2	Create BOM for autonomous driving	Shion, Camden	1/29/26	2/2/26	3	0%
2.3					0	0%
2.4					0	0%
3	**Project Conception and Initiation**					
3.1	Get brakes, Steering, Suspension move	Eric Jensen	1/26/26	2/13/26	17	0%
3.2	Generate CAD Model for Design	Zach Aszmus	1/26/26	2/11/26	15	0%
3.2.1	Run brake fluid tubes	Mech E's	1/26/26	1/30/26	4	0%
3.2.2	Install the front and rear steering systems	Mech E's	1/26/26	1/30/26	4	0%
3.3	Install brake controller	Mech E's	1/26/26	1/30/26	4	0%
3.3.1	Support wiring	Shion	1/26/26	1/30/26	4	0%
4	**Project prototyping**					
4.1	Generate 3D prints	Everyone	2/13/26	2/18/26	5	0%
4.2	Assemble test part	Everyone	2/16/26	3/13/26	27	0%
4.3	Design revision	Everyone	2/23/26	2/27/26	4	0%
4.4	Order final parts	Everyone	2/13/26	2/20/26	7	0%

Figure 3: Gantt chart developed by the autonomous platform team.

This planning tool allowed the team to provide a clear timeline for concept generation, definition and planning, and prototyping. It also helped the team identify potential bottlenecks early and ensure steady progress from each individual on the team.

2.3 Concept Generation

Following requirement prioritization and project planning, the team generated multiple autonomy concepts to explore viable solutions. In **Figures 4, 5, and 6** various line-following solutions were developed. Some other concepts include, waypoint-based navigation, vision-based lane detection, and hybrid manual/autonomous operation.

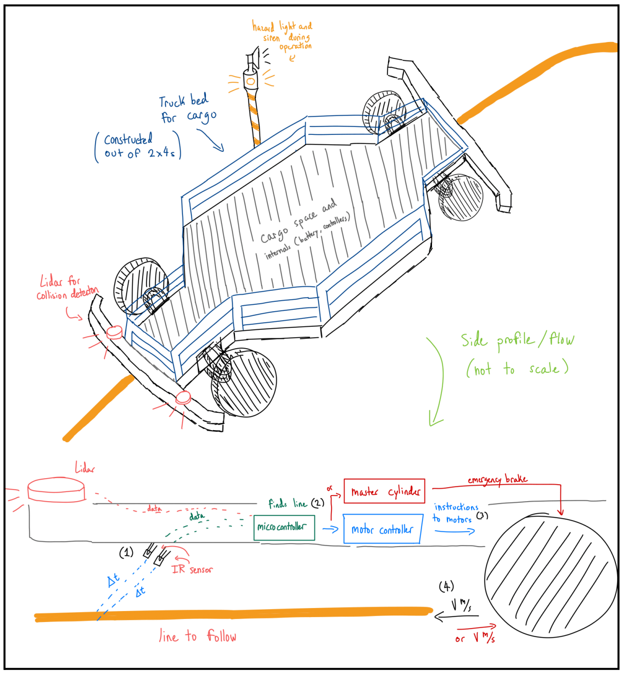


Figure 4: Line-following concept with ultrasonic and lidar sensors.

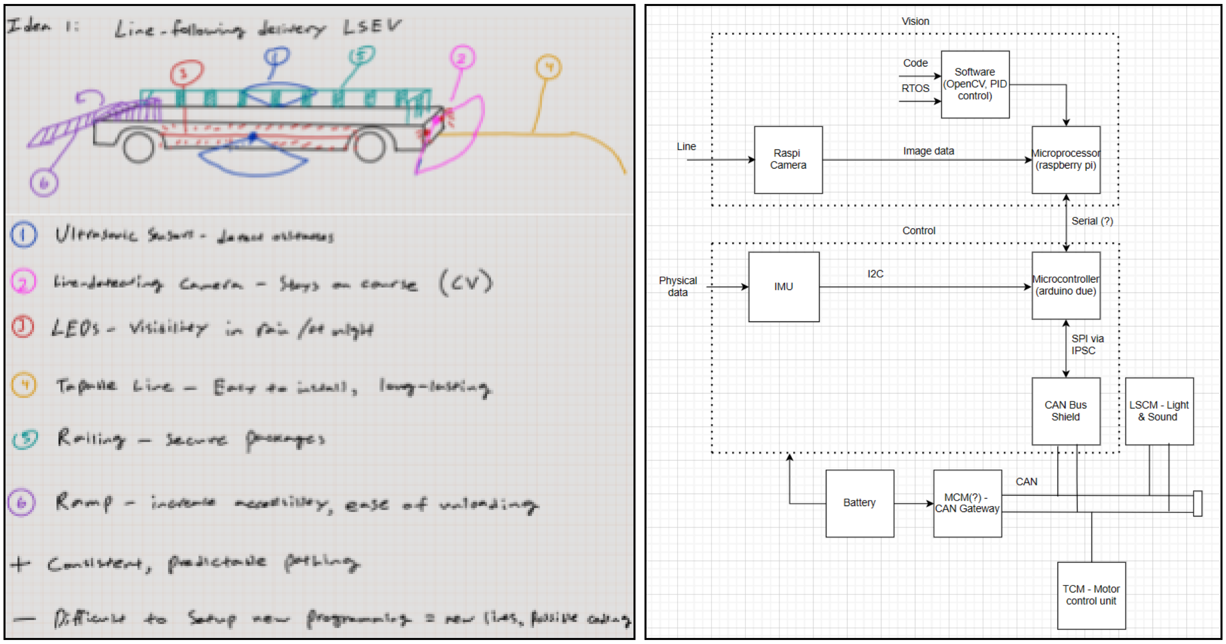
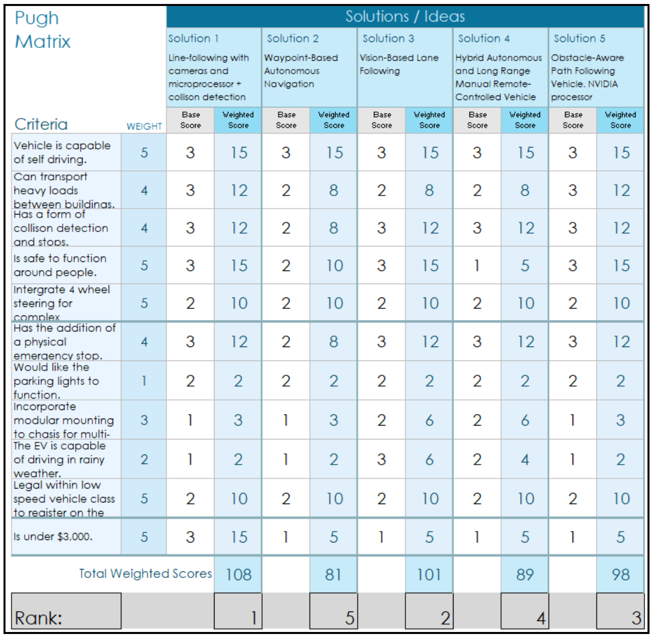


Figure 5 and 6: Line-following concept with associated block-diagram.

Concept sketches and block diagrams illustrated potential system solutions which all involved some sort of onboard processor, commonly raspberry pi or arduino, the necessary sensor inputs, and reference to CAN-based communication for vehicle control. All of the concepts prioritized a version of obstacle detection and an automatic braking system to ensure all customer safety requirements were satisfied.

2.4 Concept Evaluation Using a Pugh Matrix

To objectively compare alternatives, the team developed a Pugh matrix using evaluation criteria derived from the HOQ, seen below in **Figure 7**. Some criteria included safety, load requirements, and within the project's budget.



Pugh Matrix		Solutions / Ideas									
		Solution 1 Line-following with cameras and microprocessor + collison detection		Solution 2 Waypoint-Based Autonomous Navigation		Solution 3 Vision-Based Lane Following		Solution 4 Hybrid Autonomous and Long Range Manual Remote-Controlled Vehicle		Solution 5 Obstacle-Aware Path Following Vehicle. NVIDIA processor	
Criteria	WEIGHT	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score
Vehicle is capable of self driving.	5	3	15	3	15	3	15	3	15	3	15
Can transport heavy loads between buildings.	4	3	12	2	8	2	8	2	8	3	12
Has a form of collison detection and stops.	4	3	12	2	8	3	12	3	12	3	12
Is safe to function around people.	5	3	15	2	10	3	15	1	5	3	15
Intergrate 4 wheel steering for complex	5	2	10	2	10	2	10	2	10	2	10
Has the addition of a physical emergency stop.	4	3	12	2	8	3	12	3	12	3	12
Would like the parking lights to function.	1	2	2	2	2	2	2	2	2	2	2
Incorporate modular mounting to chasis for multi-	3	1	3	1	3	2	6	2	6	1	3
The EV is capable of driving in rainy weather.	2	1	2	1	2	3	6	2	4	1	2
Legal within low speed vehicle class to register on the	5	2	10	2	10	2	10	2	10	2	10
Is under $3,000.	5	3	15	1	5	1	5	1	5	1	5
	Total Weighted Scores		108		81		101		89		98
Rank:			1		5		2		4		3

Figure 7: Pugh matrix developed by the autonomous platform team.

The concepts evaluated were:

- Solution 1: Line-following with cameras and microprocessor with collision detection.
    - Similar to the design concept illustrated in **Figure 5.**
- Solution 2: Waypoint-based autonomous navigation.
    - Uses cones as reference points to drive along paths.
- Solution 3: Vision-Based Lane Following.
    - Similar to modern car lane-assistance systems.
- Solution 4: Hybrid autonomous and long range manual remote-controlled vehicle.
    - Long range remote-operated system.
- Solution 5: Obstacle-aware path following vehicle with NVIDIA processor.
    - Similar to how a full-self-driving Tesla or Waymo system would work with complex processing [3].

The evaluation showed that the line-following approach scored the highest due to its reliability, affordability, and aligns with the project use case. While the more advanced systems offered increased expandability of the project, it also increased with complexity of integration and cost which does not align well with the scope of this project.

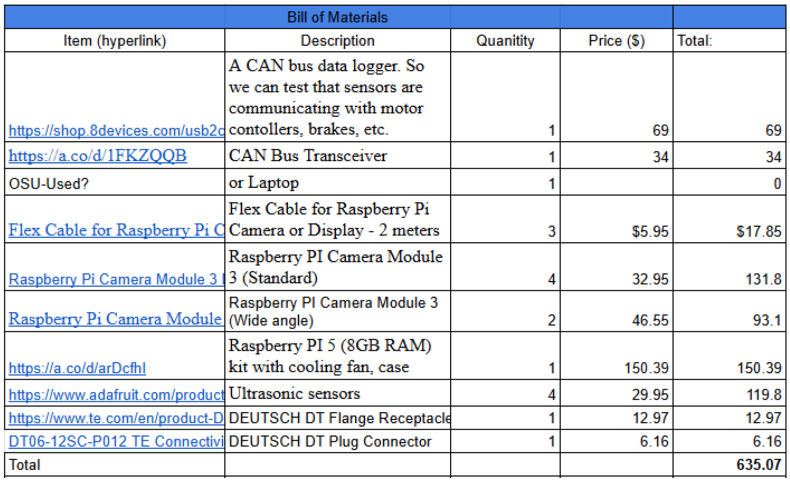
2.5 Selected Concept: Line-Following with Collision Detection

Based on the evaluation process, the team selected a line-following navigation system paired with a collision detection and emergency braking as the most appropriate solution for this project. This approach uses camera-based detection to track a marked path while maintaining steering control. Obstacle detection sensors provide automatic deceleration and stopping when hazards are detected, ensuring safe operation in a pedestrian environment.

The line-following approach was selected because it offers a reliable and easily adaptable system for this project's applications. This approach is well suited for short, repeatable routes between two fixed locations, like going between two OSU machine shops or picking cherries on a farm. Although this solution requires maintenance of the painted line and limits the route's flexibility, these tradeoffs are acceptable given the controlled environment and the project's emphasis on safety, feasibility and timely deployment. Furthermore, this is the second year of the project and serves as a base for future capstone projects to expand upon so ensuring a working prototype this year is a top priority.

3 Design Proposal

After selecting the line-following navigation strategy, the team evaluated implementation methods for deploying the autonomous system. One option involves building a custom system using individual components including, cameras, ultrasonic sensors, a Raspberry Pi, and CAN communication hardware. A preliminary bill of materials (BOM) was developed to estimate the cost and feasibility seen in **Figure 8**.



	Bill of Materials			
Item (hyperlink)	Description	Quanitity	Price ($)	Total:
https://shop.8devices.com/usb2c	A CAN bus data logger. So we can test that sensors are communicating with motor contollers, brakes, etc.	1	69	69
https://a.co/d/1FKZQQB	CAN Bus Transceiver	1	34	34
OSU-Used?	or Laptop	1		0
Flex Cable for Raspberry Pi C	Flex Cable for Raspberry Pi Camera or Display - 2 meters	3	$5.95	$17.85
Raspberry Pi Camera Module 3	Raspberry PI Camera Module 3 (Standard)	4	32.95	131.8
Raspberry Pi Camera Module	Raspberry PI Camera Module 3 (Wide angle)	2	46.55	93.1
https://a.co/d/arDcfhl	Raspberry PI 5 (8GB RAM) kit with cooling fan, case	1	150.39	150.39
https://www.adafruit.com/product	Ultrasonic sensors	4	29.95	119.8
https://www.te.com/en/product-D	DEUTSCH DT Flange Receptacle	1	12.97	12.97
DT06-12SC-P012 TE Connectivi	DEUTSCH DT Plug Connector	1	6.16	6.16
Total				635.07

Figure 8: Bill of materials for custom autonomous unit.

The BOM illustrates how a custom autonomy system could be assembled using commercially available components at an estimated cost of approximately $635. This approach offers flexibility and hands-on integration experience while allowing the system to be tailored specifically to this project. However, assembling the system entirely from individual components would introduce additional wiring complexity, software configuration challenges, and significant development time.

As an alternative, the team evaluated using a robotics-focused compute platform as the foundation of the autonomy system. Selecting between these approaches required balancing budget, development time, and project risk. Although building the system entirely from individual components would provide valuable technical experience, the team's highest priority is delivering a fully functional vehicle by the Engineering Expo. For this reason, the team selected a platform-based architecture centered on an AI-capable processor to reduce integration risk while maintaining flexibility for future development.

Real-time line tracking and obstacle detection require greater computational performance than a standard Raspberry Pi can provide. Although this increases cost, an AI-capable processor was selected because it is well suited for real-time vision processing and has demonstrated strong performance in robotics prototyping environments. **Figures 9 and 10** display a D-Robotics RDK X5 AI Developer Kit and a Jetson Orin Nano Super Developer Kit [4, 5]. While the Jetson costs $125 more than the D-Robotics platform, other OSU autonomous vehicles such as the GFR car have demonstrated the Jetson to be reliable in a competitive environment.

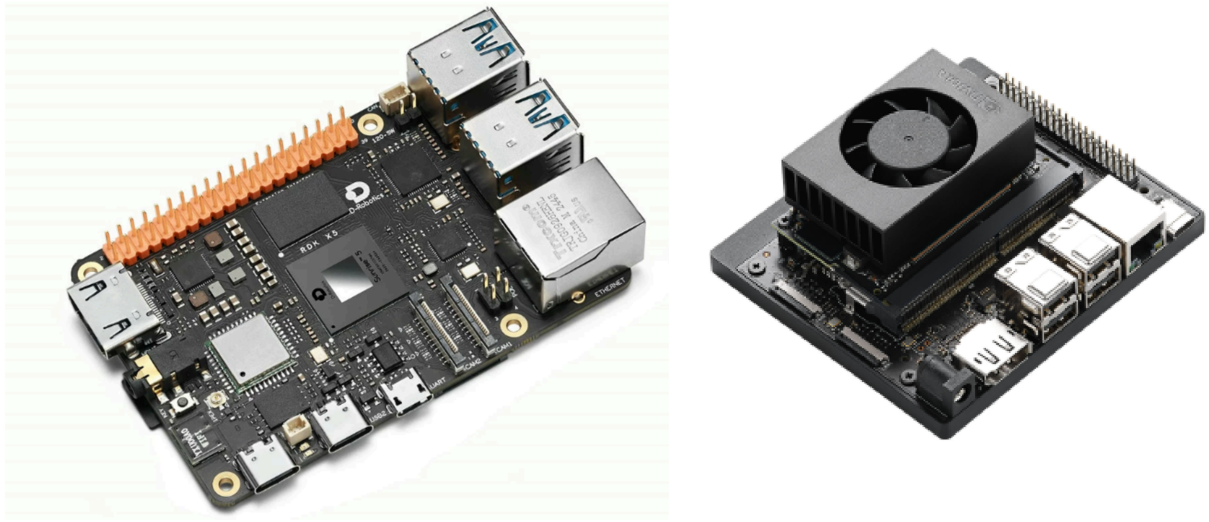


Figure 9 and 10: D-Robotics RDK X5 AI Developer kit (left) and Jetson Orin Nano Super Developer Kit (right) [4, 5].

Changing the processor will require new cameras better suited for the Jetson platform. Likely used will be several IMX219 Camera Sensor NVIDIA Jetson Nano's seen in **Figure 11** [6] . The cameras will face forward for obstacle detection as well, some will face the ground to pick up the high-contrast line painted on the ground.

Figure 11: IMX219 Camera Sensor NVIDIA Jetson Nano [6].

The code programmed to accomplish this project will be written in Python and C++ with reliance on open source libraries pre-adapted to AI vision systems. The team will design and 3D print housings for the camera and processors to fit the system onto the LSEV. To accomplish motor control, CAN-based hardware will be purchased as seen in **Figure 8** that will allow communication between the Jetson and the motors. This will require extensive prototyping and testing which will be allocated to the Spring term of this project.

During the testing phase, safety will be the top priority. A secondary master cylinder will be purchased and installed for redundancy [7]. This system will have a remote emergency stop button that an operator could press to stop the LSEV during the testing phase and further be used during transportation between OSU iLabs.

Updating the BOM to include the emergency braking system and additional hardware increases the estimated system cost to approximately $1,050. Although this requires a larger portion of the $3,000 budget allocated for autonomy and four-wheel steering integration, the investment improves navigation reliability and provides redundant braking capability to ensure safe operation between OSU iLabs facilities.

4 Conclusion

The proposed autonomous low-speed electric vehicle platform advances the existing Woodpecker chassis by integrating a reliable line-following navigation system, obstacle detection, and a redundant safety system. Through a structured design process that prioritized stakeholder requirements, evaluated alternatives, and assessed implementation tradeoffs, the team selected a line-following system with collision detection as the most practical and dependable solution for operation between OSU iLabs.

To ensure successful deployment within the project timeline, a platform-based autonomy architecture powered by an AI-capable processor was selected. This approach reduces integration risk while providing sufficient computational capability for real-time vision processing and future system expansion. The addition of redundant braking and emergency stop functionality further strengthens operational safety during testing phase and final deployment.

Looking forward, the team will order the system components defined in the BOM, fabricate mounting hardware, integrate sensors and control systems, and conduct testing to validate navigation accuracy, obstacle detection reliability, and braking performance. Route preparation, including high-contrast line marking and controlled testing environments, will support safe deployment.

This platform establishes a functional foundation for future capstone teams to expand autonomy capabilities and explore additional applications such as agricultural automation. By delivering a reliable working prototype, the project advances sustainable material transportation solutions while supporting Oregon State University.

Work Cited

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