VASAVI COLLEGE OF ENGINEERING

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VCE-EFx

SDC 2025

PROJECT REPORT BY

TEAM SPROCKET

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TEAM SPROCKET adopted a multidisciplinary collaborative model, integrating expertise from Mechanical Engineering and related technical fields to ensure a holistic approach to the project. To maximize efficiency, project responsibilities were strategically partitioned into specialized functional areas, including conceptual development, design validation, CAD modeling, hardware fabrication, iterative testing, and comprehensive technical documentation.

Team info:

1. ARAVIND GOUD PANJALA (**CAPTAIN**)
2. MD. WASIF (**VICE CAPTAIN**)
3. V. SANJAY (**TECHNICAL HEAD**)
4. T. THARUN (**DESIGN HEAD**)
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12. M. LAKSHMI SHANMUKHA VALLI
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15. V. SANJITA REDDY
16. K. HANSIKA
17. A.V. SUDHA NEHA
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ASME SDC

Overview of SDC

The 2025-2026 ASME Student Design Competition tasks students with tackling the logistical and mechanical hurdles of global waste management. As urban areas grow and terrains vary, the industry struggles to balance vehicle size, collection speed, and navigational safety.
Here is a rephrased breakdown of the core challenge:
The Problem: The Balancing Act of Waste Collection
Effective waste management relies on three often-conflicting factors:

- Efficiency vs. Scale: To minimize fleet costs, companies prefer large-capacity vehicles that can sort recyclables on-site. However, these larger frames are difficult to maneuver through dense business districts and narrow streets.
- Speed vs. Safety: Vehicles are dispatched early to beat traffic, but they must operate under strict time constraints without risking property damage or hitting height-restricted obstacles like bridges and signage.
- Accessibility: In many parts of the world, standard collection is nearly impossible due to rugged terrain or inadequate storage infrastructure.

The Design Goal
The competition asks for a solution—likely a robotic or mechanical vehicle—that maximizes reservoir capacity and speed while maintaining the agility to navigate tight spaces and the low profile required to clear overhead obstructions.
Essentially, need to design a "smart" collector that is big enough to be useful, but small and nimble enough to work anywhere.

SDC 2025-2026

The AY25-26 SDC challenge is to design, fabricate, and test a versatile waste collection device that can rapidly and accurately navigate a model city with various terrains, collect and sort garbage and recycling, and transport and dump the waste materials into the correct facility (recycling center or landfill). This device must operate in a safe and efficient manner that obeys traffic and safety laws and avoids property damage or waste spillage. Points will be awarded based on the proper sorting and handling of the waste materials, as well as the size and required power source of the device.

SPROCKET's THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Project Overview:

This project presents the design and development of a remote-controlled unmanned ground vehicle (UGV) integrated with a 6-Degree-of-Freedom (6-DOF) robotic arm, specifically engineered for picking waste bins and recycle bins and dumping their contents into an onboard dumper box. The system targets the automation of waste handling operations in municipal, industrial, and hazardous environments where human involvement is risky or inefficient.

The UGV is powered by high-torque motors driven through an L298N motor driver to ensure stable movement across uneven waste-collection areas. The 6-DOF robotic arm, actuated using precision servo motors, provides human-like articulation to identify, grasp, lift, and empty bins of various sizes into the dumper box. Controlled via a wireless RF/ESP interface, the system enables safe remote operation with low latency. A microcontroller-based architecture synchronizes locomotion, arm motion, sensor feedback, and safety interlocks. Additional systems such as obstacle detection and power management enhance operational reliability.

The developed prototype demonstrates accurate bin handling, efficient mobility, and safe dumping of waste and recyclable materials, proving its suitability for automated waste collection, recycling operations, municipal cleaning, industrial handling, and emerging smart-city applications. Designed using low-cost and widely available components, the system offers high scalability for academic, commercial, and field deployment scenarios.

SPROCKET's THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Acknowledgement

It gives us immense pleasure to express our heartfelt gratitude and sincere appreciation to all those who have contributed to the successful completion of the Student Design Competition project titled "Remote Controlled Vehicle with 6 DOF Robot."

We are thankful to the Principal, **Dr. S. V. Ramana**, Vasavi College of Engineering, for granting us permission to participate in ASME EFx and for providing the necessary institutional support.
We extend our sincere gratitude to **Dr. T. Rama Mohan Rao**, Head of the Department of Mechanical Engineering, for his constant encouragement and support towards the Student Design Competition (SDC).
We are highly grateful to **Dr. P. V. S. Subhashini**, ASME Student Section Advisor, VCE Student Section, for her continuous guidance, encouragement, and valuable suggestions that helped us complete this project within the stipulated time. Her constructive feedback and motivation played a vital role in the successful execution of this work.

We would also like to express our sincere thanks to **Mr. T. Venu Gopal** for providing immense support and valuable assistance throughout the course of the project. His timely guidance and encouragement significantly contributed to overcoming various challenges during the project development.
We extend our appreciation to all the teaching and non-teaching staff for their cooperation and support. We especially thank the workshop staff for their continuous assistance and technical support throughout the fabrication and implementation phases of the project.

SPROCKET's THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Introduction

Effective waste management is essential in modern urban and industrial environments, where manual handling of waste and recycle bins exposes workers to health risks and inefficiency. To address these challenges, this project develops a **remote-controlled Unmanned Ground Vehicle (UGV)** equipped with a 6-Degree-of-Freedom (6-DOF) robotic arm designed to pick up waste and recycle bins and dump their contents into an onboard dumper box.

The combination of a mobile platform and a multi-DOF robotic arm enables the system to navigate different terrains and perform precise tasks such as grasping, lifting, and overturning bins. The robotic arm, modelled after human arm movement, provides wide flexibility, allowing accurate handling of bins of various sizes. Wireless remote control through RF/ESP communication ensures safe operation from a distance, making the system suitable for hazardous or hard-to-reach environments. The robot integrates DC motors, servo motors, motor drivers and microcontrollers to achieve synchronized control and stable performance. Its design emphasizes structural strength, balanced weight distribution, and reliable power management to ensure smooth lifting and dumping operations. Beyond waste management, the system is adaptable for material handling, object sorting, and industrial tasks in contaminated or restricted areas.

Overall, the project demonstrates a cost-effective, safe, and efficient robotic solution that supports smart-city waste management and reduces human exposure to unsafe working conditions.

SPROCKET's THOUGHT

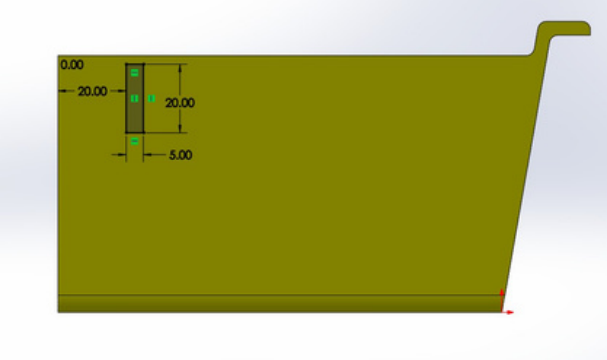
REMOTE CONTROLLED WASTE COLLECTION VEHICLE

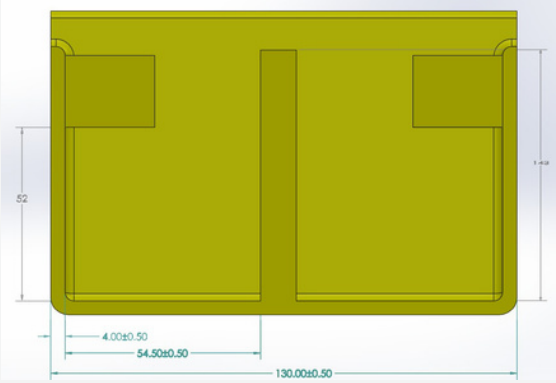
Methodology and Design Process

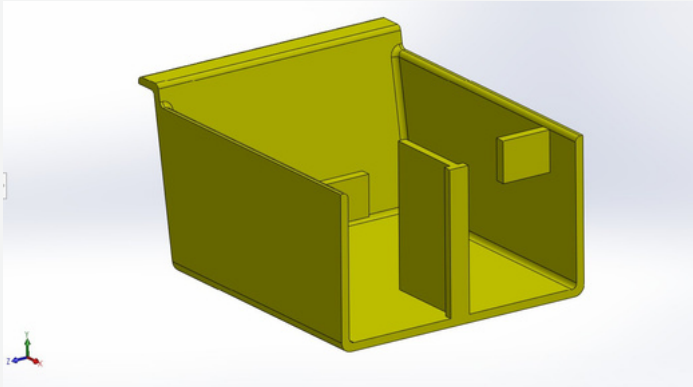
1. Conceptual Design and Structure

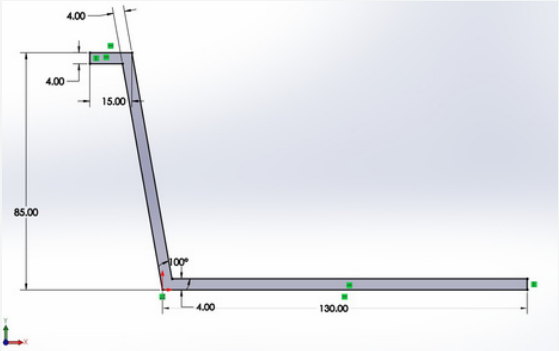
The project followed a systematic design approach to create a remote-controlled Unmanned Ground Vehicle (UGV) capable of automated waste handling. The core architecture is divided into three main physical modules:

- Vehicle Chassis: A robust 4-wheel drive (4WD) platform provides the necessary mobility to navigate uneven waste-collection areas.
- 6-DOF Robotic Arm: A serial manipulator designed to mimic human articulation, enabling the system to identify, grasp, and lift bins of varying sizes.
- Onboard Dumper Box: A 3D-printed yellow structure serves as the final containment reservoir for waste. It features a motorized hinge mechanism for emptying collected materials.





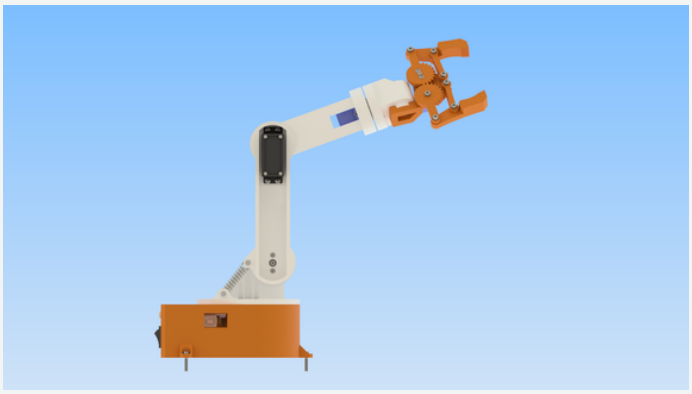




SPROCKET’s THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Methodology and Design Process



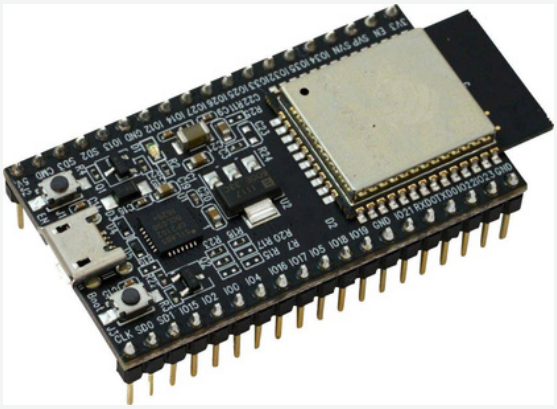
SPROCKET's THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Methodology and Design Process

2. Hardware and Electronic Architecture

The system's intelligence is centered around an ESP32 Dev Board, which acts as the primary microcontroller. It manages high-level tasks like RF/Wi-Fi communication on one CPU core while simultaneously calculating motor kinematics on the second core.



Key Components include:

- Actuators: High-torque MG996R servo motors drive the primary arm joints for structural reliability, while lightweight SG90 servos handle low-load tasks like gripper movement.
- Locomotion: Four DC gear motors (12V) are controlled via an L298N motor driver to ensure stable, omnidirectional movement.
- Control Interface: A radio-frequency (RF) remote control with dual-axis joysticks provides intuitive, low-latency manual operation.
- Power Supply: A 4V 2000mAh rechargeable lithium-based battery pack provides a stable power source for the sensors and controllers.

SPROCKET's THOUGHT

REMOTE CONTROLLED WASTE COLLECTION VEHICLE

Methodology and Design Process

Implementation and fabrication

1. Fabrication and Material Selection

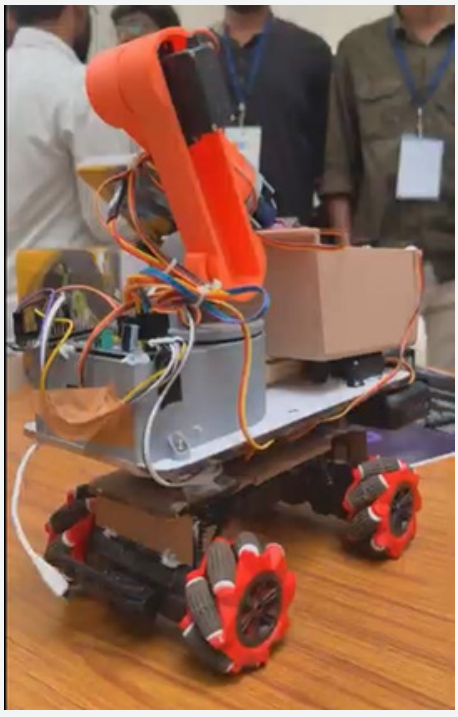
To ensure high dimensional accuracy and rapid prototyping, the robotic arm, gripper, and dumper components were fabricated using 3D printing.

- Material: PLA (Polylactic Acid) filament was selected for its rigidity, lightweight properties, and ease of printing.
- Parameters: Components were printed using a 0.4 mm nozzle with a layer height of 0.16–0.20 mm to balance strength and detail.

2. Software and Kinematic Integration

The movement of the 6-DOF arm is achieved through Inverse Kinematics (IK).

- Targeting: The user defines a target position (e.g., a waste bin handle), and the control program mathematically calculates the six joint angles required for the gripper to reach that coordinate with the correct orientation.
- Synchronization: The ESP32 code utilizes the Adafruit_PWMServoDriver library to coordinate multiple joint movements simultaneously.
- Communication: Wireless commands are received via the ESP-NOW protocol, allowing the system to switch between "Home" positions and manual operational modes with minimal latency.



3. Assembly and Testing

The final assembly integrated the 3D-printed mechanical components with the electronic control suite on the RC chassis. During testing, the vehicle demonstrated efficient navigation and successful pick-and-place operations. While the prototype proved the concept, testing revealed that the shoulder servo required additional torque to handle heavier payloads, a finding that will guide future design iterations.

Participation of
TEAM SPROCKET at VCE-EFx SDC

Competition experience and performance analysis

1. Initial Testing and Navigation Phase

The competition commenced with an intensive initial testing round, providing a five-minute window to evaluate the model's performance on the designated playfield. During this phase, the primary objective was to validate the integration between the ESP32 microcontroller and the 4-Wheel Drive (4WD) chassis.

- **Operational Success:** The vehicle demonstrated exceptional maneuverability and stability, successfully navigating the complex terrain of the playfield without incurring any safety violations or boundary penalties.
- **Manipulator Challenges:** While the drive system performed reliably, the 6-DOF robotic arm faced significant challenges in its first live application. Although the MG996R servo motors provided substantial theoretical torque (approx. 9 kg·cm), the team was unable to successfully execute a full lift of the waste bins within the allotted time. This was attributed to the precise alignment required for the gripper to engage the bin handles, a task complicated by the high-pressure environment of the live testing round.

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Competition experience and performance analysis

2. Elimination Round: Competitive Performance

Advancing to the elimination round, the team was tasked with a ten-minute head-to-head challenge against an opposing team on a significantly larger playfield. This stage required simultaneous navigation, bin retrieval, and waste dumping into the onboard 3D-printed dumper box.

- **Tactical Execution:** Our model successfully navigated its assigned side of the arena, moving into position to engage the waste units. The team came remarkably close to achieving a successful lift and dump sequence, demonstrating the effectiveness of the Inverse Kinematics (IK) programming used to coordinate the six independent joints of the arm.
- **Power Management Issues:** The most critical technical hurdle encountered during this round was unexpected power depletion. The high-current demands of the multiple MG996R high-torque servos quickly exhausted the 4V 2000mAh battery pack. As the battery voltage dropped, the torque output of the servos diminished, leading to a significant reduction in the arm's workability and payload capacity. This power-train limitation ultimately prevented the completion of the dumping sequence.

Participation of
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Competition experience and performance analysis

3. Results and Technical Conclusions

Despite the power-related setback in the final minutes of the elimination round, our team's consistent navigation and advanced structural design were recognized by the judges.

- **Final Ranking:** Based on the cumulative score of navigation efficiency, technical design, and overall presentation, our team secured 3rd position in the competition.
- **Lessons Learned:** The experience highlighted a critical need for enhanced power management systems. Future iterations will prioritize a higher-capacity power source and potential gear-reduction mechanisms to reduce the current draw on the servo motors. The competition successfully validated the modular design of the PLA-fabricated components and the responsiveness of the RF-based remote control system, proving that the core architecture is sound but requires optimized energy distribution for long-duration tasks.

Participation of

TEAM SPROCKET at VCE-EFx SDC

THANK YOU