Power and self-management:

1. Power Source:

Energy efficiency:

The excellent energy density and capacity of the 18650-lithium rechargeable battery have made it widely known. This is because of its lightweight profile, casual design, dependable performance, and long-life cycle—which, in regular use, can surpass 500 cycles, more than double the life of the available battery. With a typical capacity of 2000–3500 mAh and voltage of 3.6–4.2 volts, each cell enables the vehicle to run for extended periods of time between recharging sessions. The lithium-ion chemistry's efficiency guarantees little energy loss, enabling the vehicle's systems to make efficient use of most of the stored energy.

Weight:

While we considered using a power bank, since it couldn't provide the ampere, we required and it weighed heavier than batteries, we ultimately decided against it. Since our mission requires a fast speed, weight was an important point to look after, and we had found that compared to other battery technologies, the 18650 battery is significantly lighter while offering higher energy capacity, reducing the overall weight burden on the vehicle and increasing our acceleration.

Vehicle Power Requirements:

The vehicle's power needs are efficiently met by the 3 x 18650 batteries used, which makes it a total of around 10.8v to 12.6v, which provide consistent and stable power to operate motors that require a total of 8v to 11v, sensors, and processing units.

Power-Saving Features:

To maximize operational time, power-saving techniques such as placing sensors in sleep mode when not actively required are employed. Certain sensors may only be activated when critical data is needed, reducing the total energy draw.

2. Sensor Selection:

Ultrasonic Sensors:

Purpose: Ultrasonic sensors are primarily used for close-range obstacle detection and proximity sensing. It was used to detect the direction or robot movement and the empty spaces the robot can pass through, as well as the walls it should avoid. We used 2 ultrasonics on each side in addition to one in the front and another in the back, making it a total of 6 ultrasonics since we required high accuracy and precision. We eventually were able to use the ultrasonic on both sides to adjust our robot to face the desired angle from the wall by moving the robot in both directions until both ultrasonics were equal in value, which was a challenge we faced.

Justification for Selection: Ultrasonic sensors are highly effective in environments where obstacles or other vehicles may be present at close distances, which was the case with the inner and outer walls and obstacles in the challenge round. The typical detection range of an ultrasonic is 2 cm to 5 meters, with an accuracy of ±1 cm, which was required for a huge field (3 m x 3 m). Ultrasonic sensors are also robust against varying lighting conditions, making them suitable for both day and night operations.

Cameras:

Purpose: Cameras are used for detailed spatial mapping, object detection, and visual recognition. They capture high-resolution images of the surroundings, which are then processed using algorithms to identify objects, lanes, and obstacles. Our wide-angle webcam was specifically used in the obstacle round as it enabled us to detect the rgb of the obstacles ahead and quickly respond correctly to it. Additionally, it was able to respond in the right time by calculating the area of the object detected through Raspberry Pi.

Justification for Selection: A wide-angle webcam is ideal for the vehicle because it provides a broader field of view, allowing the system to capture more of the surrounding environment in a single frame. This is particularly useful for object detection and spatial awareness, as the vehicle can monitor a wider area, reducing blind spots and improving decision-making in complex or cluttered environments. Additionally, the wide-angle view enhances the camera's ability to track obstacles and moving objects, improving overall navigation and safety during operation.

3. Sensor Integration:

In this setup, the **Arduino Nano** is dedicated to handling the **ultrasonic sensors**, while the **Raspberry Pi 5** processes data from the **webcam**. The **Raspberry Pi 5** and **Arduino Nano** communicate with each other to ensure seamless integration between vision-based detection and proximity sensing. For example, if the camera identifies an obstacle far ahead, it sends instructions to the Arduino Nano, which can prepare to control the motors or adjust the vehicle's movement accordingly. This communication allows the **webcam vision** to be integrated with robot action, where the **Raspberry Pi 5** analyzes the camera data to make high-level decisions, and the **Arduino Nano** executes them by controlling the motors and servo to navigate the vehicle accordingly.

4. Power Consumption:

1. **DC Gear Motor:** Power consumption: Approx. 1W to 3W during normal operation

2. **Servo Motor:** Power consumption: Approx. 0.5W to 2.5W under normal conditions.

3. **Arduino Nano:** Power consumption: Approx. 0.15W to 0.25W.

4. **Raspberry Pi 5**: Power consumption: Approx. 10W to 25W.

5. **3 x 18650 Batteries**: Total energy storage of the pack: 7.4 Wh to 11.1 Wh per battery, totaling around 22.2 Wh to 33.3 Wh for the entire pack.

Estimated Total Power Consumption:

- At light load: Approx. 3.5W to 10W.
- Under medium load: Approx. 10W to 20W.
- At peak load: Approx. 20W to 30W.

considering medium load consumption, the robot should be able to operate for around 1 to 2 hours under typical conditions before the batteries require recharging.

Efforts to optimize power consumption:

We employed **sleep modes** on the ultrasonic sensors when it's not active.

5. Challenges and Solutions:

A challenge that faced us was the vast change of rgb of each obstacle according to the lightning, which we were eventually able to solve by using a ldr attached to the robot facing the obstacle direction.