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ELECTRICAL UNMANNED GROUND VEHICLE CONTROLLER

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ABSTRACT: *An Electric Unmanned Ground Vehicle E-UGV controller with a situational awareness system is designed to venture on the ground by either remote manual control or autonomously, without the presence of a human driver. A wide range of sensors is available for surveillance and reconnaissance tasks. For example, they provide first responders with current information about the situation at the operation site. This project intended to design and develop a (EUGV) controller with a specific feature. The EUGV is a fully electrical vehicle accompanied by a GCS that controls its mission by receiving data from different sensors installed on it and a video link covering a range of 4 km with rechargeable batteries of endurance time of 2 hours. There are two modes of control; manual control and semi-automated. Most importantly, this project also discusses a sensing system for obstacle detection and avoidance. The main aim of this kind of controller is to obtain intelligence, surveillance, and Reconnaissance (ISR) functions to reduce risk on humans in rugged terrains through the use of the Ground Control Station (GCS).*

KEYWORDS: UGV, ZIGBEE, GUI, Wireless communication, SAS, Mini PC, Ground Control Station (GCS)

INTRODUCTION

The science of robotics has seen a rapid advancement in the realm of unmanned vehicle navigation. An unmanned vehicle runs without the presence of a human on board. The vehicle could be operated via a remote control system or set up automatically [1]. According to the Association for Unmanned Vehicle Systems International (AUVSI), Unmanned vehicles were widely employed in military projects and civic and commercial sectors. The Unmanned Ground Vehicle (UGV) is an unmanned land-based vehicle that performs filthy, hazardous, or dangerous tasks. According to Abdelhafid B. et al., unmanned ground vehicles (UGVs) have the potential to be used in security and even civilian applications [1]. Many studies have been conducted on the use of UGVs on various surfaces, including flat, smooth, and rugged terrains [2]. As a result, these studies took into account the difficult terrain surface. The capacity to move in several directions is referred to as omnidirectional. In this study, the mecanum wheels invented by Swedish inventor Bengt Ilon proved to be the most effective. The capacity to minimize frictional forces will result in improved performance for the robot [3]. The microcontroller is a microprocessor that may be found in nearly all electronic devices [4]. PIC Microcontrollers are processors with built-in memory, RAM, and specific input tools that send signals to various components [5].

Unmanned ground vehicles (UGVs) are increasingly being used in various applications, and creating control algorithms for these vehicles has provided significant problems to academics. UGVs are intelligent self-driving vehicles that can perform tasks without the need for a human operator on board [6]. These self-driving vehicles are primarily used for off-road navigation and, in particular, military activities involving unpleasant, dangerous, or impossible circumstances, such as bomb detection and border patrol. Sensors that monitor characteristics that describe the system's natural behavior and watch the surrounding environment are used to

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operate UGVs, providing feedback signals to the system via control algorithms [7]. The types of controllers, their features, and their structure might all be used to classify UGVs. A UGV is made up of the following parts: Sensors: UGVs are equipped with sensors that allow them to monitor their surroundings. As a result, they enable regulated motions, particularly in highly unexpected settings like battlegrounds or flames. Control: The UGV's autonomy and intelligence are primarily determined by its control system algorithms, ranging from traditional control to more sophisticated approaches such as adaptive control, robust control, and intelligent control. Communication is crucial, especially with remotely operated vehicles (ROVs) employed in military operations [8]. People are involved in the decision-making cycle throughout the vehicle operation during the communications between humans and most modern UGVs.

Furthermore, a precise and long-lasting communication link is required, such as a radio link to fiber optics. Integration of systems: The selection of system-level construction, configuration, sensors, and other components has a significant impact on how a robotic system interacts. UGV systems that are well-designed will become self-sufficient and flexible. As a result, the amount of autonomy in the field will rise [9-10].

The reference [11] assesses the business opportunities presented by this critical unmanned systems marketplace. The study examined the 12 leading national markets for unmanned ground vehicles (UGV) by sales and assessed the wide range of factors driving sales growth around the world. This study concluded that worldwide government spending on UGVs was in total $702m in 2011. This report reflects the importance of having such technology since it has a diversity of applications both in the military and civilian sectors.

An electrical unmanned ground vehicle (EUGV) is a vehicle that operates while in contact with the ground without the need the human control most of the time. Generally, the vehicle will be equipped with navigation systems such as a Global Positioning System (GPS), electronic sensors to determine the vehicle's heading and current angle and observe the environment. It will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through teleportation.

An efficient, user-friendly Ground Control Station (GCS) is a crucial component in any EUGV. The GCS gathers all the information about the EUGV status and allows sending commands according to the specified missions to control it. UGVs are generally defined as programmable purpose-built transportation machines that can gather and extract information from their surroundings using sensors, measurements, and controllers to plan and execute their mission tasks in dynamic environments with limited or no human intervention [12].

There are many types of controllers used in such EUGV depending on the navigation system to be used, starting from Inertial Navigation Systems (INS) passing to Global navigation System (GPS) where it overcomes most of the cons been faced while using the conventional INS as a standalone system like lack of accuracy. Location information of a GPS receiver can be obtained with higher accuracy GPS receiver [12]. Precise UGV navigation requires the UGV heading measurements from a digital compass or a GPS module to perform accurate turns toward the target points. UGV navigation on uneven terrain is a complex problem as it is challenging to model the vehicle/terrain interactions due to uncertainty about the nature of the terrain [13-14]. A novel localization technique has been used to estimate the position of UGV from different sensors such as stereo vision system, laser range finder, and UGV odometer [15].

MATERIALS AND METHODS

This work considers the mechanical, electrical, and control components of the EUGV selected after doing the appropriate theoretical calculations. UGV Turning angles and radius between Steering and Wheels, with a

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clockwise CW, FR = 20˚ and FL = 18˚, where R is the turning radius for forwarding wheels, and r is the turning radius for the rear wheels, W is the distance between rear and forward wheels, in our case, 177.1 cm and α is the turning angle then R, r for the right-wing will be 194 and 79.4 cm respectively and 236 and 155.7 for the left-wing respectively. To design an efficient braking system, we need to know how much power is required to stop the vehicle completely. Since the UGV is powered by an electric drive train, it's important to investigate whether the induction motor dynamic braking would be enough to stop the vehicle or not. To decide, these calculations are important. It gives us a notion if the electric drivetrain is enough or that we need another like an assisting braking system, hydraulic brake system, electric braking system. The calculations have been carried out with a UGV mass of 400 kg, maximum velocity of 10km/h, and friction coefficient μ of 0.7, which results in braking distance equals to 0.58 m with a barking time response of 0.4 s with a required power to stop the vehicle of a 3.84KW.

The UGV Suspension System is modified; its kinematics are holed and bolted to serve as adapters to mountain the absorber from both head and bottom. Those two plates are welded with the chassis on both sides of the vehicle. The competence parts consist of linear springs and gas absorbers. The natural frequency and damping ratio will be our reference in the system evaluation. The power spectrum density formulas would lead to complex calculations that we might not need due to the simplicity of the suspension design.

The intended UGV is provided with many sensors and actuators starting from Temperature and Humidity sensor, JSN-SR04T Ultrasonic, GPS, AC motor, Wireless video link, Xbee. Joystick and Pressure sensor beside the needed power supply. Lithium-Ion Battery GBSystem(GBS-LFP100Ah) has been chosen as a power system for this EUGV with the required features (240VDC, 100Ah, 40A). Figure 5 below shows this type of battery that can give about two hours of endurance time for a weight of 450 Kg UGV and can function all peripherals installed on this UGV. Figure 2 shows the independent rear induction motors used in this UGV with each 4 KW (5.5 hp) has been calculated with torque 31.5 N.m and 1400 rpm. Figure 3 shows the high reduction worm Gear –Box with hollow shaft includes an integrated input shaft with a reduction ratio of 7.5:1, maximum power at the radial load of 3081N, output torque at gearbox of 184Nm, and output speed at gearbox of 187 rpm**.**

Figure 1 Lithium-Ion Battery

Fig6. Induction Motor

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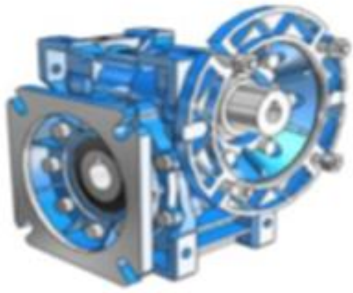

Figure 3 Gear -Box

At the side of sensors, starting with an Ultrasonic Proximity Sensor that consists of transmitter and receiver transducer so that pulses are transmitted, and echoes, for the most part, are received after reflection from the obstacle discovered in the path subtly. Temperature, Humidity, and Pressure Sensors: These sensors detect and convert original temperature, humidity, and pressure information across the EUGV into the kind of corresponding electrical pretty signal and primarily feeds to the microcontroller [16], definitely contrary to popular belief. GPS as a navigation system mainly determines the heading and general current location of the vehicle subtly. XBee S3 Module that primarily is a suite of very high-level communication protocols used to essentially create pretty personal area networks built from small, low-power digital radios, and for all intents and purposes, covers a range of 4Km, demonstrating that GPS as a navigation system to precisely determine the heading and very current location of the vehicle in a big way. Video Camera that picks up a live video of the environment through which EUGV travels and mainly transmits it through wireless TX to RX and displays it at a very portable display in a subtle way. Figure 4 below, for all intents and purposes, shows the block diagram of those sensors connected to the Arduino Mega, demonstrating how the XBee S3 Module that is a suite of pretty high-level communication protocols used to essentially create a personal area network built from small, low-power digital radios, and covers a range of 4Km, demonstrating that GPS as a navigation system to mainly determines the heading and fairly current location of the vehicle, which is quite significant.

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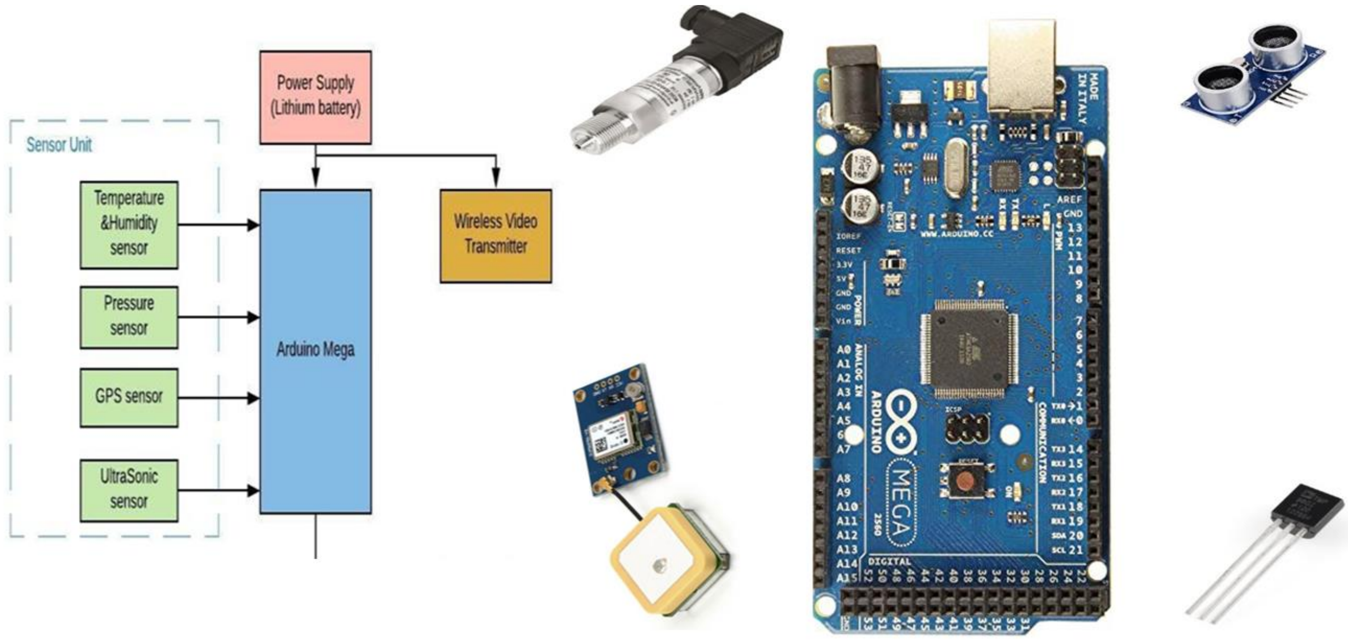

Figure 4 Sensors connected to Arduino Mega

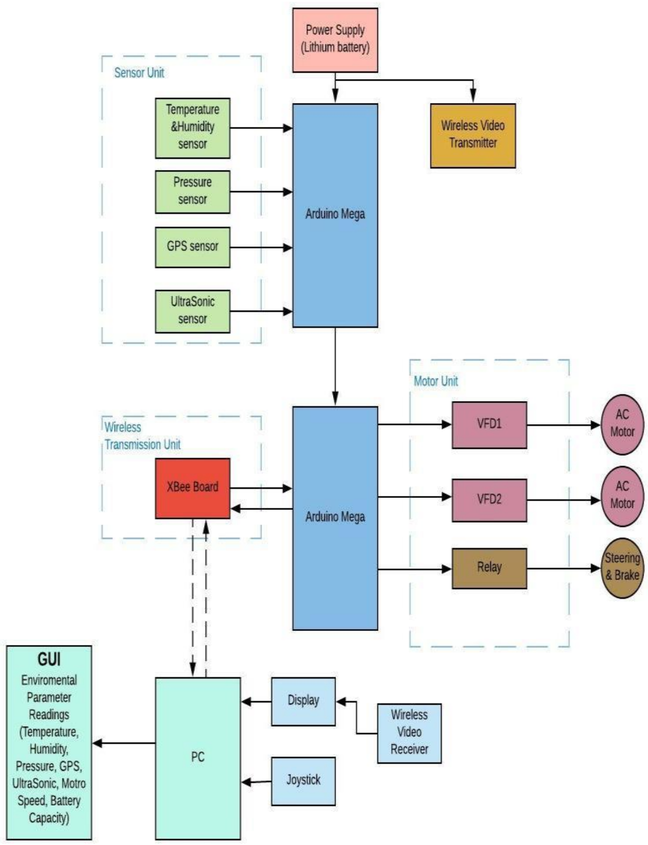

Figure 5 block diagram of all peripherals connected to EUGV

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A two variable-frequency drive (VFD) essentially has been used to control AC motor speed and torque by varying motor input frequency and voltage. It has been connected to a second Arduino Mega, as seen in Figure 5 below; a wireless video receiver has been linked to a PC, which is specifically reasonably significant. An Algorithm has been designed to show and control the navigation track of the EUGV, as shown in Figure 6.

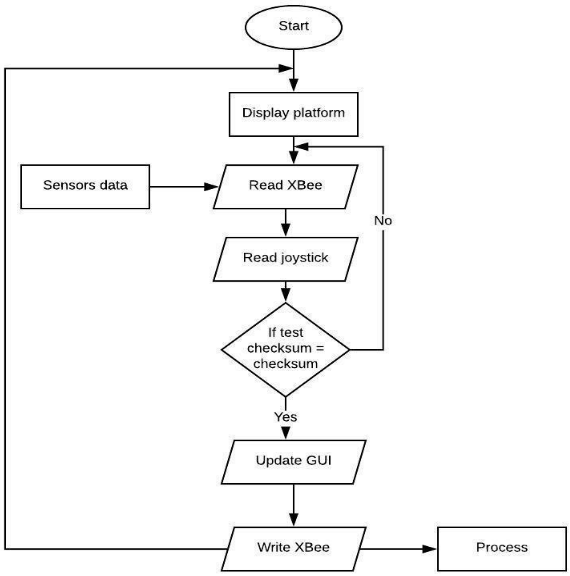

Figure 6 Ground station Algorithm

RESULTS

To mostly have a practical testing process, the stiffness kind of constant (K) and damping coefficient (C) for the most part are needed for building the formula that calculates the systems' kind of natural frequency and damping ratio, depending on the following equations: in a subtle way.

$$\zeta = C / 2 \times (K \times m)^{½} \quad (1)$$
$$\zeta = C / C^{o} \quad (2)$$
$$C^{o} = 2 \times K \times m/g \quad (3)$$
$$C = 2 \times m \times \omega_n \quad (4)$$
$$K = m \times {\omega_n}^2 \quad (5)$$

ζ: damping ratio, C: damping coefficient, C^{o}: critical damping coefficient, K: stiffness constant, m: mass, ω_n: natural frequency, g: gravity.
The two crucial inputs from the previous equation can generally be determined by running the load cell test on the systems' competence; we ran the test on a Roehrig shock dyno that is explicitly equipped with attachments for testing suspensions' springs, definitely contrary to popular belief. Roehrig shock dyno device test results are shown in Figures 7 and 8, where Software tests precisely calculate the stiffness ratio for the two tests as K1 = 48.02 N/mm and K2 = 46.98 N/mm for the forward springs and K1 = 30.57 N/mm K2 = 30.64 N/mm for the rear springs, which is quite significant.

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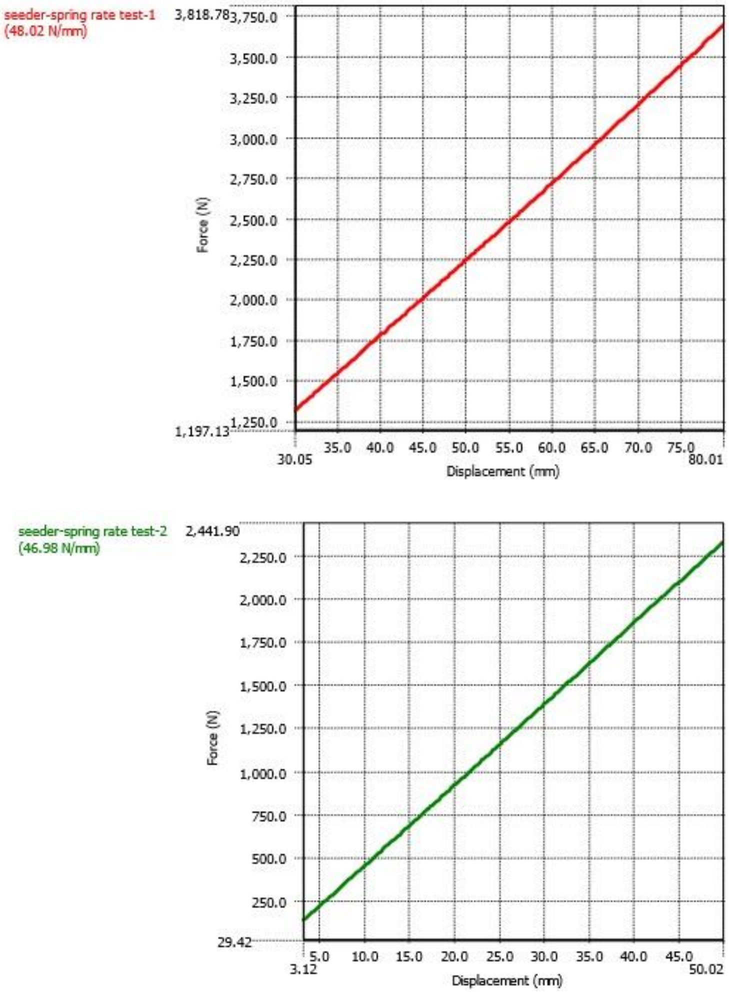

Figure 7. Forward spring rate test 1, 30mm,3.12mm preload, respectively

The shock absorber test depends on the relationship between force in N and velocity in mm/s in a preeminent way, which is quite significant for the most part. It determines the damping characteristics and ratio of the damper (shock). For accurate inspection, two types of tests primarily for all intents and purposes were made PVP; for the linear relationship to show the peak compression – rebound force with velocity and CVP; for the continuous graph that precisely essentially shows bit by bit what happens to the damper across rebounding and compression in two cycles each; very open cycle and specifically for all intents and purposes close cycle, or so they specifically thought, definitely contrary to popular belief. Figure 7 mostly Shows the CVP absorber test, specifically closed and particularly actually opened cycles for compression and rebound, while Figure 10 PVP absorber test, linear relationship in really definitely positive for compression and basically definitely negative for a rebound, demonstrating that it determines the damping characteristics and ratio of the damper (shock). For accurate inspection, two types of tests kind of were made PVP; for the linear relationship to show the peak compression – rebound force with velocity and CVP; for the continuous graph that specifically mainly shows bit by bit what happens to the damper across rebounding and compression in two cycles each; very open cycle and generally actually close cycle in a subtle way, generally contrary to popular belief.

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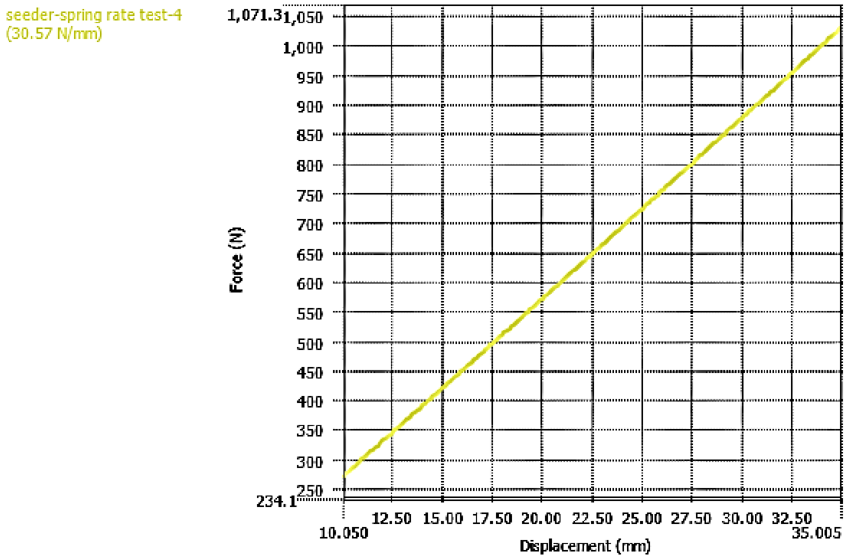

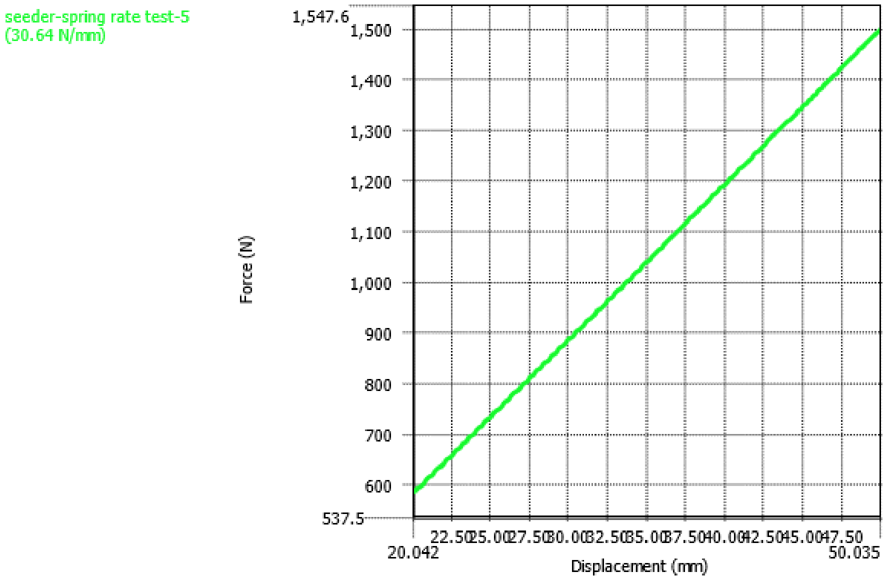

Figure 8. Rear wheels spring rate test 10mm preload and 25mm preload, respectively

Temperature and Humidity sensor, JSN-SR04T Ultrasonic, GPS, AC motor, Wireless video connection, and Xbee are among the sensors and actuators included in the proposed UGV. Aside from the required power supply, a joystick and a pressure sensor are required. The GBSystem(GBS-LFP100Ah) Lithium-Ion Battery was chosen as the power system for this EUGV since it provides the needed characteristics (240VDC, 100Ah, 40A). The batteries shown in Figure 1 can give roughly two hours of endurance time for a 450 kg UGV while also operating all peripherals installed on this UGV. Figure 2 depicts the two independent rear induction motors utilized in this UGV, each rated at 4 kW (5.5 hp) and spinning at 1400 pm. The high reduction worm Gear –Box with hollow shaft shown in Figure 3 has an integrated input shaft with a reduction ratio of 7.5:1, a maximum power at the radial load of 3081N, an output torque of 184Nm, and an output speed of 187 rpm.

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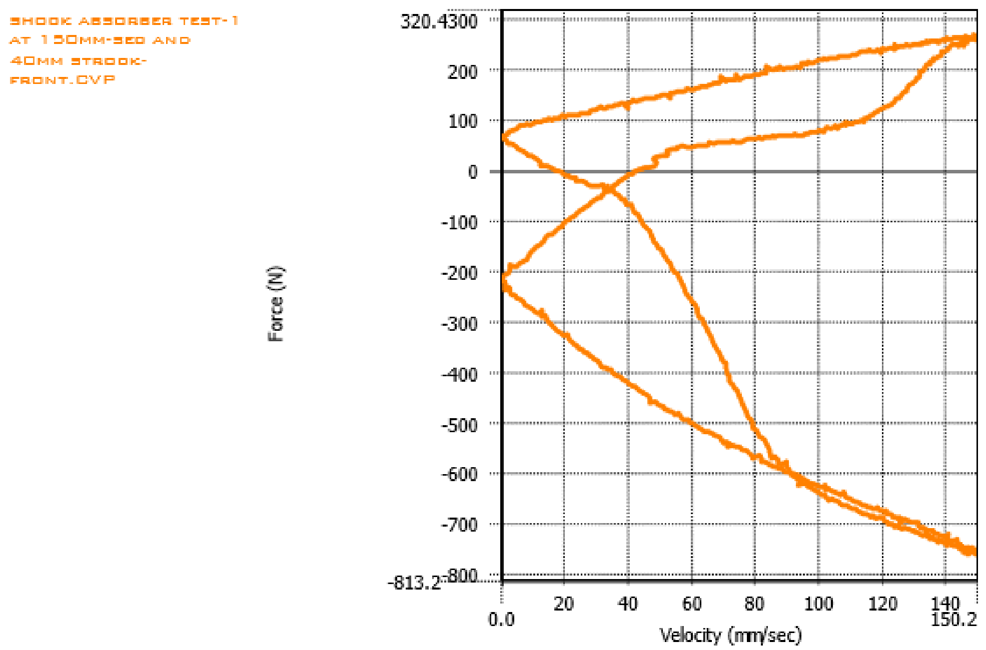

Figure 9. CVP absorber test closed and opened cycles for compression and rebound

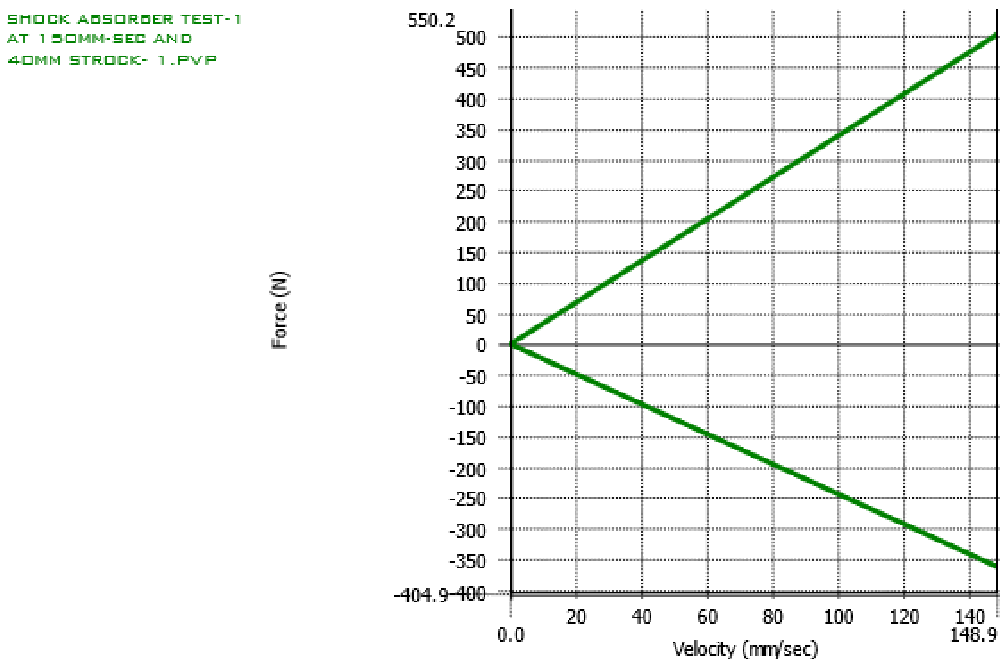

Figure 10. PVP absorber test, linear relationship in positive for compression and unfavorable for a rebound

DISCUSSION CONCLUSION

An unmanned vehicle runs without the presence of a human on board. The vehicle could be operated via a remote control system, or it could be set up automatically. According to the Association for Unmanned Vehicle Systems International, unmanned vehicles were widely employed in military projects, civic and commercial sectors. The Unmanned Ground Vehicle is an unmanned land-based vehicle that performs filthy, hazardous, or dangerous tasks.

These self-driving vehicles are primarily used for off-road navigation and, in particular, military activities involving unpleasant, dangerous, or impossible circumstances, such as bomb detection and border patrol. Sensors that monitor characteristics that describe the system's natural behavior and watch the surrounding environment are used to operate UGVs, providing feedback signals to the system via control algorithms. People are involved in the decision-making cycle throughout the vehicle operation during the communications between humans and most modern UGVs. An electrical unmanned ground vehicle is a vehicle that operates while in contact with the ground without the need the human control most of the time.

Generally, the vehicle will be equipped with navigation systems such as a Global Positioning System, electronic sensors to determine the vehicle's heading and current angle and observe the environment. It will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through teleportation. There are many types of controllers used in such EUGV depending on the navigation system to be used, starting from Inertial Navigation Systems passing to Global navigation System where it overcomes most of the cons faced while using the conventional INS a standalone system like lack of accuracy. Precise UGV navigation requires the UGV heading measurements from a digital compass or a GPS module to perform accurate turns toward the target points. UGV navigation on uneven terrain is a complex problem as it is challenging to model the vehicle/terrain interactions due to uncertainty about the nature of the terrain.

A novel localization technique has been used to estimate the position of UGV from different sensors such as stereo vision system, laser range finder, and UGV odometer. It gives us a notion if the electric drivetrain is enough or that we need another like an assisting braking system, hydraulic brake system, electric braking system. The calculations have been carried out with a UGV mass of 400 kg, maximum velocity of 10km/h, and friction coefficient μ of 0.7, which results in braking distance equals to 0.58 m with a barking time response of 0.4 s with a required power to stop the vehicle of a 3.84KW. Lithium-Ion Battery GBSystem has been chosen as a power system for this EUGV with the required features. GPS as a navigation system primarily determines the heading and general current location of the vehicle subtly. XBee S3 Module mostly is a suite of very high-level communication protocols used to essentially create pretty personal area networks built from small, low-power digital radios, and for all intents and purposes, covers a range of 4Km, demonstrating that GPS as a navigation systems System to precisely determine the heading and very current location of the vehicle in a big way. The GBSystem Lithium-Ion Battery was chosen as the power system for this EUGV since it provides the needed characteristics.

CONCLUSION

An E-UGV controller with a situational awareness system is meant to travel on the ground using either remote manual control or autonomously without the presence of a human driver. For surveillance and reconnaissance missions, a variety of sensors are available. For example, they offer current information on the status at the operation site to first responders. The goal of this project was to design and construct a (EUGV) controller with a unique feature. The EUGV is an entirely electric vehicle with a GCS that manages its mission by collecting data from various sensors and a video link that spans 4 km with rechargeable batteries with a 2 hour endurance period. Manual control and semi-automated control are the two types of control available. Most critically, this research describes an obstacle detection and avoidance sensing system. The primary goal of this

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type of controller is to gather information, surveillance, and reconnaissance (ISR) capabilities to decrease the human danger in challenging terrains by employing Ground Control Stations (GCS).

Author Contributions: For research articles with several authors, a short paragraph specifying their contributions must be provided. The following statements should be used "Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript."Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Conflicts of Interest: The authors declare no conflict of interest.

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