Design and Construction of an Educational Rover-type CanSat Picosatellite, Applying the "V" Methodology

Josué Mancilla-Cerezo[1], Ana Cristina Palacios-García[2], Rafael Tovany-León[3], Ricardo Jesús Rocha-Morles[4], Jorge Luis Flores-Benitez[5], Efraín Cotto-Jiménez[6], Manuel González Pérez[7]

[1]Cuerpo Académico Aplicaciones de Tecnologías Inteligentes y Aprendizaje, departamento de Ciencias Básicas, Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México.

[2]Cuerpo Académico Aplicaciones de tecnologías inteligentes y aprendizaje, Academia de Ingeniería Sistemas Computacionales. Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México.

[3]Cuerpo Académico Aplicaciones de tecnologías inteligentes y aprendizaje, Academia de Ingeniería Tecnologías de la Información y Comunicaciones. Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México.

[4,5]alumno de Ingeniería en Tecnologías de la Información y Comunicaciones. Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México.

[6] Jefe de departamento de ciencias básicas. Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México

[7]Subdirector de investigación. Instituto Tecnológico Superior de Tepeaca, Av. Tecnológico S/N Ex-Hacienda Santa Ana, San Pablo Actipan, C.P. 75200, Tepeaca, Puebla, México.

doi: 10.51505/ijaemr.2022.7306 URL: http://dx.doi.org/10.51505/ijaemr.2022.7306

Abstract

Several years have passed since the CanSat concept was first proposed as an educational tool to teach space technology. This concept brought with it different applications such as a mobile system. This article presents the design and construction of such a system. The mission consisted of sending data via telemetry to a ground station (laptop) and returning to the starting point. This mission was carried out utilizing a rover-type vehicle, using the "v" methodology. The electronic cards and the mechanical parts that would make up the rover-type vehicle were designed. The electronic cards were built for their manufacture, and the mechanical parts were printed on a 3D printer. A rover-type CanSat capable of sending data through telemetry to a ground station (laptop) located 1 km away was built. In conclusion, the data transmission was received and

traced by the ground station. A solution is presented with the rotation of the casing incorporating some vials to the motors. In the case of DC motors, it is recommended to place encoders to maintain the same speed as both motors.

Keywords: Cansat, Rover-type, Picosatellite, V-methodology.

1. Introduction

The idea of a satellite or probes with dimensions limited to the size of a soda can was proposed by Twiggs in 1998 at the University Space Systems Conference. This idea, according to Arruabarrena et al. (2019), was to “propose the organization of annual rocket probe launch competitions. Specifically, these catheters must be the volume of a soda can and weigh no more than 360 grams, although some categories make this limit more flexible”.

According to Robayo et al. (2021), "CANS AT-type missions are recognized by educational centers (primary, secondary or university) as didactic, multidisciplinary and collaborative processes aimed at promoting pedagogical and investigative skills so that young people interested in the study of aerospace sciences. In this sense, Arruabarrena et al. (2020) detail that "these missions allow learning and exercising engineering, electronics, programming, sensors and other disciplines associated with a satellite project. Students build or use models of small satellites following a process that takes them through the different stages that a satellite mission must go through, for example, design, construction, test, validation, execution, analysis and obtaining results".

The CanSat is limited by controlled descent employing a built-in parachute, but this satellite must be recovered once it hits the ground. For this reason, the event organizers have implemented a category for the CanSat to land without damage. The cant sat in this category can autonomously return to the launch site by clearing terrain obstacles. Autonomous Rover systems fit this category. The term Rover was coined for the LRVs, or Lunar Roving Vehicles launched to the moon to explore this satellite on the Apollo 5, 16, and 17 space missions (NASA, 2013). According to NASA, two characteristics were distinguished, the first was to overcome irregularities in the terrain, and the second was navigation, where “The navigation system had to allow the astronauts to return to the lunar module (LM). This system was based on dead reckoning.ead reckoning is a system from a known point that constantly determines the distance traveled and direction. (NASA, 1970).

The term Rover was coined for the LRVs, or Lunar Roving Vehicles launched to the moon to explore this satellite on the Apollo 5, 16, and 17 space missions (NASA, 2013). According to NASA, two characteristics were distinguished, the first was to overcome irregularities in the terrain, and the second was navigation, where “The navigation system had to allow the astronauts to return to the lunar module (LM). This system was based on dead reckoning. Dead reckoning is a system from a known point that constantly determines the distance traveled and direction. (NASA, 1970).

For Huertas (2018), “It is said that an autonomous vehicle is one capable of combining numerous techniques, included in its hardware and software, of being able to move without requiring the help of a driver. The elements that make up the hardware are those capable of perceiving the environment, while the software comprises the complex algorithms that receive said information and issue a decision. The best route and assess the environment.

For students to learn to design simulated space missions with CanSat and adapt them to mechanisms of autonomous Rover-type vehicles, the use of Gowin's UVE model or diagram is proposed as a learning method for the modeling of systems instruments and parts. Mechanics associated with telemetry and the Rover.

For Herrera (2012), "One of the fundamental components of science teaching is the practical laboratory work through which students have the opportunity to meet the scientific processes inherent to science. Students' curiosity, interest, and motivation in the face of practical experiences represent a valuable opportunity to develop scientific inquiry skills and allow them to carry out school science, bringing them closer to the way scientists work. "For this, Moreira (2007) proposes "the V diagram as a potentially facilitating heuristic instrument of significant learning, from an epistemological perspective, that is, of knowledge as a human production."

According to Dori (2002), referenced in Bermúdez (2016), this methodology reduces time and costs by identifying risks on time, guaranteeing the design's quality and operation from the didactic point of view.

Bermúdez (2016) proposes the UVE diagram to “combine the requirements and results of a mission. The left side, mission needs. Right side, integration and mission verification, middle part, system fabrication and correlation of integration requirements.” Secondary phrase one and essential binary relation.

Methodology “v” What is it? Characteristics and properties, evolution.

2. Method

The methodology of the “V” diagram was used since it has been proven that if applied correctly, it can give excellent results to win a national contest (Mancilla et al., 2017), (Mancilla, Palacios, Pérez, and Torija, 2018).

This methodology follows the phases: pre-phase, phase A, phase B, phase C, phase D, phase E, and phase F (Bermúdez, 2016).

Pre-phase: conceptual study and selection of mission to develop

Within the conceptual study, It can find different rover missions carried out by the National Aeronautics and Space Administration (NASA, for its acronym in English), ranging from the first rover of its kind, such as Lunokhod (Kassel, 1971) to and Sojourner (NASA, 1997); that with the success of their respective missions immensely helped the development and construction of the following rovers for the exploration of the planet Mars: Spirit and opportunity (Leger et al., 2015), Curiosity (Benowiz, 2014) and Perseverance (NASA, 2020). In the middle of this year, the missions will be carried out: Exomars (SENER, 2020) and HX-1 (LATAM, 2020), where both carry their rover vehicles with them.

The mission was selected, and data on internal and external temperature, relative humidity, altitude, longitude, latitude, battery level, acceleration, magnetic field, and tilt were sent. Telemetry to a ground station was used for this database.

Phase A: development of the concepts and techniques to be used

The mission requirements are presented in Table 1.

Table 1. Mission requirements.

System requirements	Subsystems covered	Goals
It should be 146 mm in diameter and 240 mm long.	Power, computer, mission, communication, and chassis.	Design a compact and shock resistant architecture.
Maximum mass 1 kg.	Power, computer, mission, communication, and chassis.	Design lean systems, selecting low-weight materials and devices.
CanSat power will be supplied by battery.	Power.	Selecting a battery that is capable of supplying power to electronic components and motors for at least 30 minutes.
The battery must be easily accessible.	Chassis.	Diseñar este subsistema de modo que el cambio de batería no afecte a los demás subsistemas y sea manipulable fácilmente.
The CanSat must have a main switch in an accessible place.	Chassis.	It should have the on/off button at the top.
Recovery system	Recovery.	Build a parachute that ensures optimal recovery of the CanSat.
Descent speed between 5 and 12 m / s.	Recovery.	Design the parachute to descend at 5 m / s.
Transmission range greater than 1 km.	Communication.	Select a device capable of maintaining communication during the ascent and descent.
Rover system for the return to the starting point.	Power, computer, mission, communication, and chassis.	Power: supply the necessary energy for sending data and motors for the return to the starting point. Mission: contain the sensors, actuators for the success of this. Computer: ensure the proper functioning of the mission. Communication: send the vehicle's position in real time via GPS. Chassis: structural sufficiency to withstand weight and shock. House two motors, stack, and all other subsystems.
Measurement of temperature (external and internal), pressure, relative humidity, latitude, longitude, altitude, acceleration, vibration, battery level and video.	Power, mission, communication, and computer.	Power: must have the necessary voltage for all devices and space to power the camera. Mission: must house all sensors. Communication: it must house space for the GPS. Computer: must have a programmable device.

Based on what is described in Table 1, the devices were selected to achieve the success of the mission as far as possible. These devices are presented in Table 2.

Table 2. Selected devices

Activity	Device
Measure external temperature and relative humidity	DHT 11
Measure altitude, acceleration, magnetic field, inclination, and internal temperature	GY-87
Measure Longitude and Latitude	GY-NEO6MV2 GPS
Take Video	Mini spy camera
Computer and data sending	Arduino pro mini and Xbee S3
Rover vehicle	Arduino pro mini, chassis and tire design, 3D printing, motors and L298N controller
Parachute releasing device	Mini servo motor

3. Results

Phase B: preliminary architectural designs to accomplish the mission

Selecting the devices and keeping in mind the way in which the pico-satellite would rise, as can be seen in Figure 1.

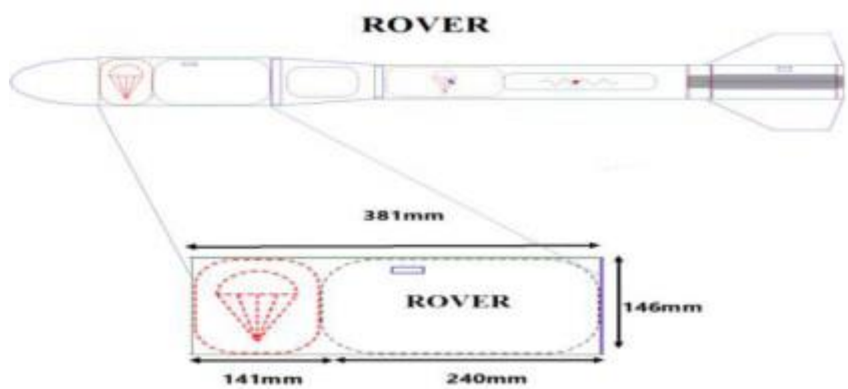

Figure 1. Location of the rover on the rocket to be promoted.

Preliminary sketches of the EagleSat V2.2 architecture were made. Greater dimension was given to the rims. This increase in tires was to withstand the impact in case the parachute does not open on descent. In this way electronic devices are protected. In addition to the above, the engine rotation conflict was minimized by differentiating the speed and rotation of the chassis. These conflicts are mentioned by Mancilla, Palacios, Pérez, and Jiménez (2019). For the first conflict, encoders for the tires were considered as controlling the speed of the motors. For the second conflict, the chassis was attached to the wheels using bearings. This joint was made so that the turning of the engines would not transmit torque to the chassis.

The sketches made gave a better overview to begin with the designs and manufacture of the EagleSat V2.2.

Phase C: final designs and fabrication

With the sketches and ideas generated in Phase B, the designs were made: the mechanical ones printed on a 3D printer in PLA material and the electronic design manufactured by the ironing method to obtain the printed circuit.

Mechanical designs included: tires, bearing clamps, and driveshaft. These designs are presented in Figure 2.

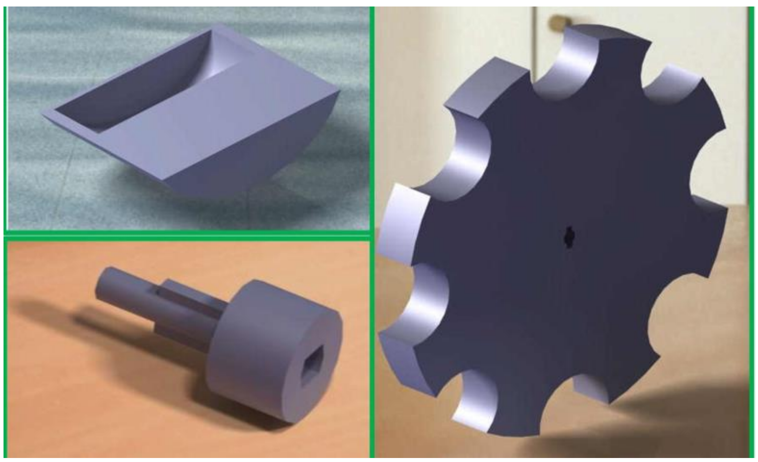

Figure 2. Bearing clamp layout (top left), driveshaft layout (bottom left), and gear type tire layout.

In Figure 3, the electronic design of the printed circuit is presented, which would accommodate all the electronic components. The design was made by putting in the upper central part of the L298N motor controller, with the objective that the center of mass would be as close to the center of the rover vehicle. On the sides of the L298N, the Arduino will be placed, one in charge of the management of the sensors and the sending of data to the Xbee; the second Arduino will be responsible for managing the encoders and activating the pins of the L298N. The central part of the design is the power stage and a space for the servo motor. In the lower central part, there will be the embedded GY-87, and at its sides, the global positioning system (GPS, for its acronym in English) and the Xbee that will oversee communication with the earth station (laptop).

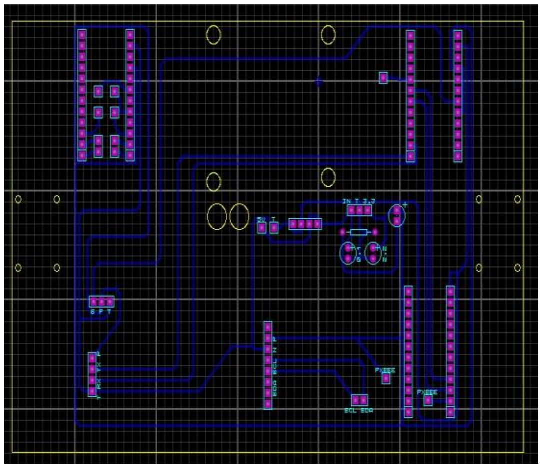

Figure 3. Printed circuit design.

Later the manufacture of the designs began. Figure 4 shows an already printed rim and part of the printed circuit manufacturing process, such as ironing and drilling.

a) b) c)

Figure 4. a) Printed rim. b) Ironing of Printed c) Circuit drilling

Phase D: Integration

In this phase, the integration of all the mechanical and electronic elements that would make up the EagleSat V2.2 was carried out. The wheels were integrated with the arrows, and these with the bearings and clamps. This integration was made to place the already coded motors. All of this can be seen in figure 5.

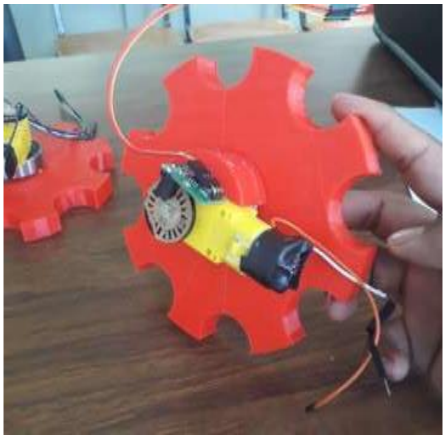

Figure 5. Motor-tire integration.

In Figure 6 the integration of the electronic and mechanical components is presented.

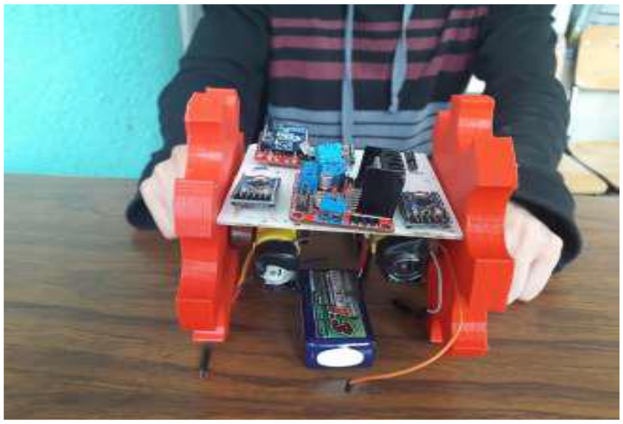

Figure 6. Integration of mechanical and electronic parts.

4. Discussion

Phase E: System

The integration of all the elements was carried out correctly according to the EagleSat V2.2 system (see figure 7).

EagleSat V2.2 navigation depends on the Gy-87 sensor compass and GPS. EagleSat V2.2 orients itself towards the polar north, and its global latitude and longitude position is known from compass data. These data are stored in the memory of the microprocessor. When the Eagle Sat starts its "return home" algorithm, the first step is to orient itself, then it advances and compares the latitude and longitude data it has stored and its current position. This comparison subtracts the stored value with the value current; if the result is negative, the rotation of the motors is inverted if the positive result continues advancing until the comparison is less than 0.1.

Vol. 7, No. 03; 2022

ISSN: 2456-3676

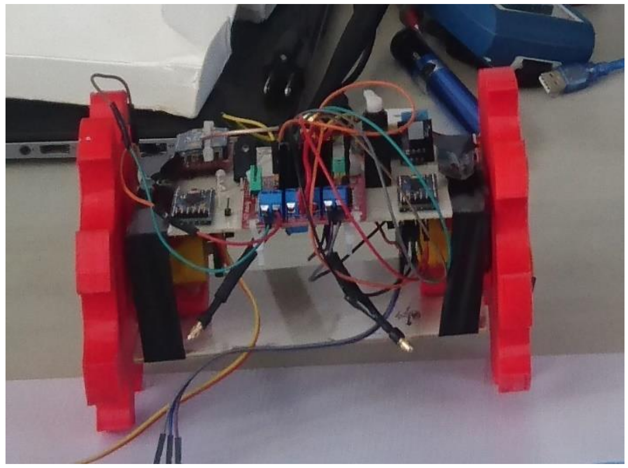

Figure 7. EagleSat V2.2 Pico-satellite.

Phase F: Mission.

The application of the V model was a success. That is, the EagleSat V2.2 picosatellite was designed and built. We participated in the Fifth National CanSat Educational Picosatellite Contest in the rover (comeback) category with this satellite. We got third place. In this way, it is concluded that with the accurate monitoring of model V. In Figure 8, the students expose their rover to the contest judges. Likewise, the exact figure shows the third place of EagleSat V2.2

Figure 8. Exhibition before judges (left) and third place category comeback

It is stated that the proper follow-up of the “V” diagram methodology ensures the success of a CanSat mission.

ISSN: 2456-3676

Regarding the speed of the motors, using encoders removes the problem that one motor turns more than another, but it is necessary to have independent control of the sensors so that there are no conflicts or waiting times in testing them.

In the case of chassis rotation, this conflict was minimized by having the bearings very well lubricated. Since now lubrication is lost, the chassis rotates again. It was also observed that there is more chassis rotation at higher engine speeds. Due to this observation, it is recommended to have the bearings well lubricated and a low speed of the motors.

The design and construction of the EagleSat V2.2 rover was a success since it was possible to participate in a national competition of this nature and obtain a third place.

Acknowledgments

Identify grants or other financial support (and the source, if appropriate) for your study; do not precede grant numbers by No. or #. Next, acknowledge colleagues who assisted in conducting the study or critiquing the manuscript. Do not acknowledge the persons routinely involved in the review and acceptance of manuscripts peer reviewers or editors, associate editors, and consulting editors of the journal in which the article appears. This paragraph also explains any special agreements concerning authorship, such as if authors contributed equally to the study. End this paragraph with thanks for personal assistance, such as manuscript preparation.

References

Arruabarrena, M., Fernández, A., Medel, R., & Mori, L. (2019). Estudio bibliográfico del estado del arte del desarrollo y aplicaciones educativas de CanSats. X CATE.

Robayo, R. A., Meneses, J., Imbacuan, B., Gómez, Y., Najar, R., Fuentes, C., Riocampo, S., & Correa, J. (2021). *Misiones tipo Cansat: Una estrategia para el Fomento de las Tecnologías Aeroespaciales en los Estudiantes de Ingeniería de la Emavi-Fac.* Encuentro Internacional de Educación En Ingeniería. Recuperado a partir de https://acofipapers.org/index.php/eiei/article/view/1806.

Arruabarrena, M., Báez, L., Fernández, A., Lammers, M., Marengo, E., Medel, R., & Vicente, A. (2021). Minisatélite Cansat Aplicado al Aprendizaje Basado en Problemas en Diversos Contextos Educativos. Jornadas de Ciencia y Tecnología 2020 “50 aniversario”, 105.

NASA. (1995). Lunar Roving Vehicle: Historical Origins, Development, and Deployment, Bettye B. Burkhalter and Mitchell R. Sharpe, Journal of the British Interplanetary Society, Vol. 48, pp. 199-212.

NASA. (1970). The Navigation System of the Lunar Roving Vehicle, by W.G. Heffron and F. LaPiana, Bellcomm, NASA TM 70-2014-8,

Huertas Martín, M. (2018). Diseño de interfaz hombre-máquina para vehículo autónomo (Bachelor's thesis).

Vol. 7, No. 03; 2022

ISSN: 2456-3676

Herrera, Edith. (2012). La UVE de Gowin como instrumento de aprendizaje y evaluación de habilidades de indagación en la unidad de fuerza y movimiento. Paradigma, 33(2), 101-126

Moreira, M. A. (2007). Diagramas V y aprendizaje significativo. Revista chilena de educación científica, 6(2), 1-13.

Bermúdez, B. (2016). Cansat: lata-satélite. CiENCiA UANL. 19, (81), p. 71-75.